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PRINCETON, NEW JERSEY

INSTRUCTION MANUAL

TWO-PHASE LOCK-IN AMPLIFIER

MODEL JB-6

Ser # 301

Covered under one or more of the following U.S. Patents: #3,270,213, #3,296,463, #3,296,464.

THIS MANUAL APPLIES SPECIFICALLY TO MODEL JB6 SERIAL NO. 301

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2. Your name (instrument user).
3. Your address.
4. Address to which instrument should be returned.
5. Your telephone number and extension.
6. Symptoms (in detail, including panel settings.)
7. Your purchase order number for repair charges (does not apply to repairs in warranty.)
8. Shipping instructions (if you wish to authorize shipment by any method other than normal surface transportation.)

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The malfunction is_____

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Please return instrument to me at (address)

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MY PAR EQUIPMENT REQUIRES SERVICE

It is a Model #_____, Serial #_____

The malfunction is_____

Name_____, Title_____

Company_____

Address _____

Telephone_____, Ext._____

Please return instrument to me at (address)

Via (shipping method)_____

Signed_____

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MANUAL CHANGE

Page I-3, under "(4) ORTHOG", should read:

Provides internal calibration signal for adjustments of orthogonality between channels to within $\pm 1°$ from 3 Hz to 30 kHz, and $\pm 5°$ from 1.5 Hz to 3 Hz and from 30 kHz to 150 kHz.

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SECTION I
SPECIFICATIONS

1.1 GENERAL

(1) FREQUENCY RANGE

1.5 Hz to 150 kHz, continuously tunable in five ranges.

(2) GAIN (single-ended rms in to push-pull DC out)

Greater than 9,000 for each channel. One-half millivolt rms input signal in-phase with reference will drive IN-PHASE meter to full scale. One-half millivolt rms input signal in quadrature with the reference signal will drive QUADRATURE meter to full scale. "In-phase mixer gain" (I GAIN) control provides a convenient adjustment for making the gain of the two channels identical.

(3) NOISE REJECTION

Maximum internal time constant permits the recovery of either component of a signal 46 dB below ambient white noise in a 1 kHz bandwidth centered about signal frequency with a signal-to-noise ratio of one.

(4) EQUIVALENT INPUT NOISE

Equivalent input noise with the input terminals shorted in a 1/40 of a Herz bandwidth is approximately 1/2 microvolts rms. To detect lower level signals of the order of microvolts, use PAR™* Model CR-4 Pre-Amplifier.

(5) EQUIVALENT BANDWIDTH

0.025 Hz minimum (10 seconds maximum internal RC integrating time). 6 or 12 dB per octave roll-off selectable by front panel switch for each channel.

(6) TIME CONSTANTS

0, 0.001, 0.01, 0.1, 1, 3, 10 seconds, and EXT. Single or double section RC filtering. In the EXT. position appropriate points internal to the instrument are brought out to a rear connector where capacitance may be added to obtain any desired time constant. Independent controls and EXT. CAP connectors are provided for each channel.

(7) HARMONIC REJECTION

Second harmonic down by a factor of 1000 or 60 dB. Third harmonic down by a factor of 200 or 46 dB.

*PAR is a trademark of Princeton Applied Research Corporation.

(8) OVERLOAD INDICATION

Light indicates overload condition at critical circuit points.

(9) LINEARITY

Better than ±1% of full scale for each channel.

(10) ZERO DRIFT

±1/2% of full scale per hour maximum for each channel.

(11) POWER REQUIREMENTS

105 - 125 volts or 210 - 250 volts; 50 - 60 Hz; 10 watts.

(12) PHYSICAL

(a) Weight - Approximately 15 pounds.

(b) Size - 19" W x 7" H x 13" D

(13) ACCESSORIES

PAR Model CR-4 and CR-4A Preamplifiers and Model 125 and 126 Mechanical Light Choppers.

1.2 SIGNAL CHANNEL CHARACTERISTICS

(1) INPUT IMPEDANCE

Approximately 50 k.

(2) INPUT LEVEL CONTROL

Input signal may be attenuated up to a factor of 1000 in steps of 1.0, .5, .2, .1, .05, .02, .01, .005, .002, .001; accuracy ±5%.

(3) FREQUENCY SELECTIVE AMPLIFIER

Selectivity characteristics of tuned amplifier in signal channel is that of parallel resonant circuit with a Q of approximately 25. (Not twin-T type.)

1.3 REFERENCE CHANNEL CHARACTERISTICS

The reference signal, by which the signal to be measured is demodulated, is obtained in three modes of operation; INTERNAL, EXTERNAL, and SELECTIVE EXTERNAL. The ORTHOG position provides an internal calibration signal for adjustments of orthogonality between channels.

(1) SELECTIVE EXTERNAL MODE

Externally generated reference signal filtered by tuned amplifier

having characteristics of parallel resonant circuit with a Q of approximately 25, phase shifted and applied directly to demodulators. Minimum of 100 millivolts peak-to-peak reference signal required.

(2) EXTERNAL MODE

Externally generated reference signal phase shifted and applied directly to demodulators. Five volts peak-to-peak reference signal required.

(3) INTERNAL MODE

Self-contained oscillator drives demodulators (through phase shifter) directly. Output frequency appears as sine wave at REFERENCE IN/OUT terminals. Maximum output approximately five volts peak-to-peak at three mA maximum.

(4) ORTHOG

Provides internal calibration signal for adjustments of orthogonality between channels to within +1° from 3 Hz to 30 Hz and +5° from 1.5 Hz to 150 kHz.

(5) PHASE ADJUSTMENT

Provides minimum of 180° of continuous phase change at any frequency. Also 180° INVERT switch.

1.4 OUTPUT

Will drive most galvanometric or servo recorders. Also direct reading panel meters. Independent outputs for each channel available simultaneously at the rear of instrument.

(1) LEVEL

Maximum DC output for each channel

(a) into high impedance load ±5 volts.

(b) into pen recorder of less than 2 k resistance ±1 milliamp or ±1/2 milliamp (switch selectable).

(2) COMMON MODE QUIESCENT VALUE

-6 volts DC.

1.5 MONITOR

A four position switch allows the panel MONITOR METER and MONITOR output terminals to be switched to the SIGNAL, REFERENCE, QUADRATURE, or IN-PHASE outputs for level monitoring, setting-up and zeroing. The MONITOR METER indicates peak-to-peak AC voltage when it is switched to the REFERENCE and SIGNAL positions.

SECTION II
PRELIMINARY INSTRUCTIONS

2.1 GENERAL

COOLING

Because of the low total power consumption of the instrument, its case is unventilated. At installation the only precaution to be observed is to insure that the ambient temperature in which it is operated does not exceed 45°C (113°F). This will insure trouble-free continuous operation.

POWER REQUIREMENTS

The instrument requires approximately 10 watts at either 105 to 125 volts AC or 210 to 250 volts AC; 50 to 60 Hz. It is normally shipped wired for 105 to 125 volts operation. If it is shipped wired for 210 to 250 volt operation, the line cord will bear a tag at the plug end so marked. Transformer primary connections for operating at either 117 volts or 234 volts AC are illustrated in Figure II-1 and the procedure for changing from one to the other is outlined below.

(1) Remove the top, bottom, and back sheet metal covers.

(2) Remove the right (viewed from the front) side panel by removing the 4 screws securing it to the printed circuit board assembly, and the 2 screws securing it to the front panel. Easy access to the power transformer may now be had from the right side of the instrument.

(3) The transformer primary connections for 117 volt operation are shown in Figure II-1A.

(4) The transformer primary connections for 234 volt operation are shown in Figure II-1B.

FUSING

A 0.4 A. slo-blo 3 AG 250 V. fuse is installed in the primary circuit of the power transformer. It gives adequate protection to the instrument in either 117 volt or 234 volt operation at either 50 or 60 Hz. A 0.3 A. slo-blo fuse is used in the power supply rectifier circuit. FUSES OF HIGHER RATING SHOULD NOT BE USED IN EITHER CIRCUIT.

2.2 FRONT PANEL CONTROLS AND CONNECTIONS

POWER

In the OFF position this switch completely disconnects the instrument from the power line.

SIGNAL LEVEL

This control sets the fraction of the voltage applied to the SIGNAL INPUT

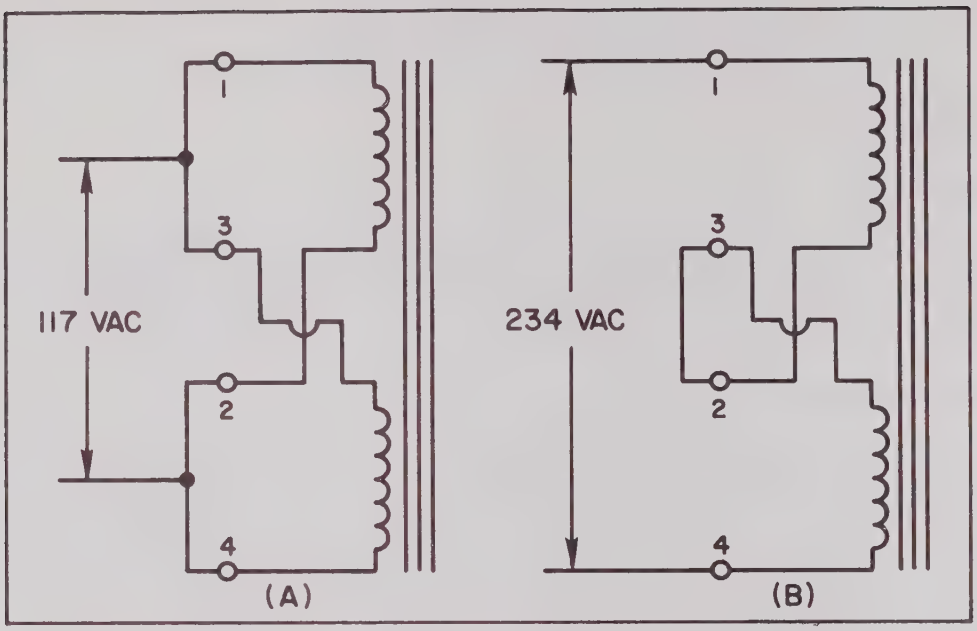

Figure II-1. TRANSFORMER PRIMARY CONNECTIONS FOR OPERATION FROM EITHER 117 VAC OR 234 VAC SUPPLY

terminals which reaches the input of the signal channel tuned amplifier.

SIGNAL INPUT

The signal input circuit is single-ended. The red binding post is the "high" side, and the black binding post is connected to chassis ground. A resistance of 54 k ±5% (the resistance of the SIGNAL LEVEL control) is internally connected directly across these terminals.

CAUTION: THE VOLTAGE (DC + PEAK AC) APPLIED BETWEEN THESE TERMINALS SHOULD NEVER EXCEED 25 VOLTS.

FREQUENCY

This control tunes both the reference channel and the signal channel tuned amplifiers. The reference frequency in Hz. is the reading on the scale multiplied by the factor set by the FREQ RANGE switch. The accuracy of this frequency setting is ±5%.

FREQUENCY RANGE

This switch selects the range which can be continuously tuned by the FREQUENCY dial. This setting applies to both the signal and the reference channel.

FREQUENCY TRIM

This control varies the frequency of the signal channel tuned amplifier only. Total variation is approximately ±5%. It is used to peak the signal channel at any particular frequency setting, thus compensating for possible errors in tracking between the signal and reference tuned amplifiers, or between the signal channel and the internal reference oscillator.

PHASE

This control varies the phase of the reference voltage. It provides a continuously variable shift of at least 180° at any frequency within the range of the instrument.

REFERENCE MODE

This switch is used to select one of the four modes of operation of the reference circuit. (See OPERATING INSTRUCTIONS, Section III, for a detailed description of the reference modes).

REFERENCE LEVEL

In both the SEL EXT and EXT modes, this control selects a fraction of the voltage connected to the REFERENCE IN/OUT terminals and applies it to the following Reference Channel Circuitry. In the INT. mode it controls the level of the internally generated sinusoidal voltage appearing at the REFERENCE IN/OUT terminals.

REFERENCE IN/OUT TERMINALS

In the EXT reference mode, these terminals connect to the input of the phase shifter via the REFERENCE LEVEL control. In the SEL EXT mode, these terminals connect to the input of the reference channel tuned amplifier via the REFERENCE LEVEL control. The red binding post is the "high" side of the single-ended input, the black binding post being connected to chassis ground. In either mode a resistance of 54 k ±5% (the resistance of the REFERENCE LEVEL control) is connected directly across these terminals.

In the INT. reference mode a sine wave voltage at the reference frequency appears at these terminals. Its amplitude is set by the REFERENCE LEVEL switch. With this switch in the "1" position the sine wave output is approximately five volts peak-to-peak. In any other position the output is the indicated fraction of this value. The output from these terminals is single-ended, the red binding post being the "high" side and the black binding post being chassis ground. The effective source impedance at these terminals varies with the REFERENCE LEVEL setting. It has a maximum value of approximately 1.4 k when the switch is in the "0.5" position.

In the ORTHOG reference mode there is no voltage at these terminals.

CAUTION: THE VOLTAGE (DC + PEAK AC) APPLIED BETWEEN THESE TERMINALS SHOULD NEVER EXCEED 25 VOLTS.

RESPONSE TIME

These two switches determine the time constants of the low-pass RC filters in the output circuits of the two demodulators. The number at each switch position gives the corresponding time constant in seconds. In the OFF position there is no internal low-pass filtering. In the EXT. position the filtering time constant is determined by external capacitors.

6 dB, 12 dB PER OCTAVE SWITCH

This switch sets the roll-off of the RC low-pass filter to either 6 dB/OCTAVE (single RC filtering) or 12 dB/OCTAVE (double RC filtering). In either case the time constant of the filter is set by the switch position. This switch is also operative when external capacitors are used.

INVERT

These two switches (one in each demodulator circuit) invert the phase (i.e. produce a 180° phase change) of the reference voltage. Inverting a reference voltage has the effect of inverting the sense of the corresponding output at the panel meter and at the OUTPUT terminals.

ZERO

These controls set the DC level of the output. They are normally used to set the panel meter to zero with no signal input.

MONITOR SELECTOR

This switch performs two functions. It determines the internal point in the instrument monitored by the MONITOR METER and simultaneously connects the same point to the MONITOR terminals for oscilloscope monitoring.

MONITOR METER

In the SIG position of the MONITOR SELECTOR, this meter measures the signal voltage at the input to the in-phase demodulator. In the REF position, it measures the output of the reference phase shifter.

In the Q OUTPUT position of the MONITOR SELECTOR, the MONITOR METER is connected as a DC voltmeter with a full scale value of approximately five volts. It measures the output of the quadrature circuit. In the I OUTPUT position, the MONITOR METER is switched to the in-phase circuit, the connections otherwise being the same as in the Q OUTPUT position.

NOTE: In both the Q OUTPUT and I OUTPUT positions of the MONITOR SELECTOR, the meter marked QUADRATURE is connected as a DC voltmeter measuring output of the quadrature circuit, with full scale sensitivity the same as that of the MONITOR METER. In the SIG and REF positions of the switch, this meter is disconnected.

MONITOR TERMINALS

This group of three terminals provides for oscilloscope monitoring of all

important internal waveforms and also provides a low-impedance voltage output from the instrument for special uses. The waveform appearing at these terminals depends on the setting of the MONITOR SELECTOR switch.

(1) SIG position

The right-hand red binding post is connected to one side of the push-pull quadrature output of the signal amplifier. The other red binding post is similarly connected to the in-phase output of the signal amplifier. Both binding posts are at a DC potential of -6 V relative to chassis ground. The black binding post is permanently connected to ground in all positions of the switch.

(2) REF position

The right-hand red binding post is connected to the output (single-ended) of the reference phase shifter. The other red binding post and the black binding post are both connected to chassis ground.

(3) Q OUTPUT position

The two red binding posts are connected to the output terminals (push-pull) of the quadrature channel. The black binding post is connected to chassis ground.

(4) I OUTPUT position

The red binding posts are shifted to the in-phase channel. This is the normal connection when making measurements.

I GAIN

This control (the red knob concentric with the REF LEVEL control) adjusts the gain of the DC amplifier following the in-phase demodulator. Its purpose is to equalize the gain through the two channels.

ORTHOG

The ORTHOGONALITY control provides means for adjusting the phase angle between the in-phase and the quadrature outputs of the signal channel tuned amplifier to exactly 90°.

OVERLOAD

The OVERLOAD indicator is a lamp which lights when the peak level of signal-plus-noise exceeds the linear range of the demodulators.

2.3 REAR PANEL CONTROLS AND CONNECTIONS

OUTPUT TERMINALS

These terminals provide for the connection of recorders.

±½/±1 MILLIAMPERE SWITCHES

These switches insert or short out 5000 ohm resistors in series with the output terminals. With the resistors in the circuit, the output circuits will operate recorders of less than 2000 ohms resistance which require ±½ milliampere for full scale deflection. With the resistors out of the circuit ±1 milliampere recorders can be operated.

FULL SCALE ADJUST

These are 2.5 k potentiometers which are used to adjust full scale on recorders to match full scale on the panel meters.

OCTAL SOCKETS

To get response times different from those provided by the front panel control, external capacitors may be wired to these sockets.

FUSE

This fuse is in the primary circuit of the power transformer. (NOTE: There is also a fuse in the secondary circuit of the transformer, mounted on the power supply circuit board.)

SECTION III
OPERATING INSTRUCTIONS

3.1 INTRODUCTION

The Model JB-6 Two-Phase Lock-In Amplifier is essentially a detection and measuring system capable of operating with an extremely narrow equivalent noise bandwidth. Its function is to select a band of frequencies from a signal spectrum applied to its input and to convert the information therein to an equivalent bandwidth at DC. The center frequency of the band so selected is equal to the frequency of the reference voltage. The instrument incorporates two measuring channels which simultaneously measure orthogonal components of the signal.

Figure III-1 is a block diagram of the Lock-In Amplifier. A signal voltage (which may be accompanied by electrical noise and voltages at other frequencies) is applied to the SIGNAL INPUT terminals and attenuated to a suitable level by the SIGNAL LEVEL control. The attenuated signal is applied to the signal channel tuned amplifier where it is amplified by a factor of about 50. The tuned amplifier effects an initial narrowing of the received frequency band, thus increasing the ratio of the desired signal component to the total peak voltage input and also attenuating components in the signal spectrum at odd multiples of the reference frequency to which the phase-sensitive demodulator is sensitive. (This sensitivity to odd harmonics of the reference frequency is due to the use of a switching type of demodulator.)

In the signal amplifier the signal is split into two components which are identical in frequency composition and amplitude, but are 90° apart in phase. Each component is connected to the input of a phase-sensitive demodulator. This is a device in which the signal is mixed with a reference voltage so as to produce corresponding sum and difference currents. An adjustable filter at the output of each phase-sensitive demodulator rejects the high frequency components corresponding to the sum frequencies, and passes those of the difference frequencies which lie within its pass-band. In particular the difference frequency corresponding to that component of the signal spectrum at exactly the reference frequency is zero or DC, and the zero-frequency current is the useful output of the instrument. The very low frequency currents adjacent to zero modulate the useful output, but they can be suppressed to any desired degree by the low-pass filter at the cost of increasing the time constant of the amplifier output.

The phase-sensitive demodulators are so designated because their output is a function of the phase angle between the signal voltage and the reference voltage. The reference voltage for this instrument may be generated internally or obtained from an external source. In either case, a variable phase shifter is available in order to allow the relative phase of the signal and reference to be adjusted as desired.

3.2 PANEL METER ADJUSTMENT

Before power is applied to the instrument the zero correcting screws on the two meters should be adjusted so the pointers rest exactly on zero. Then

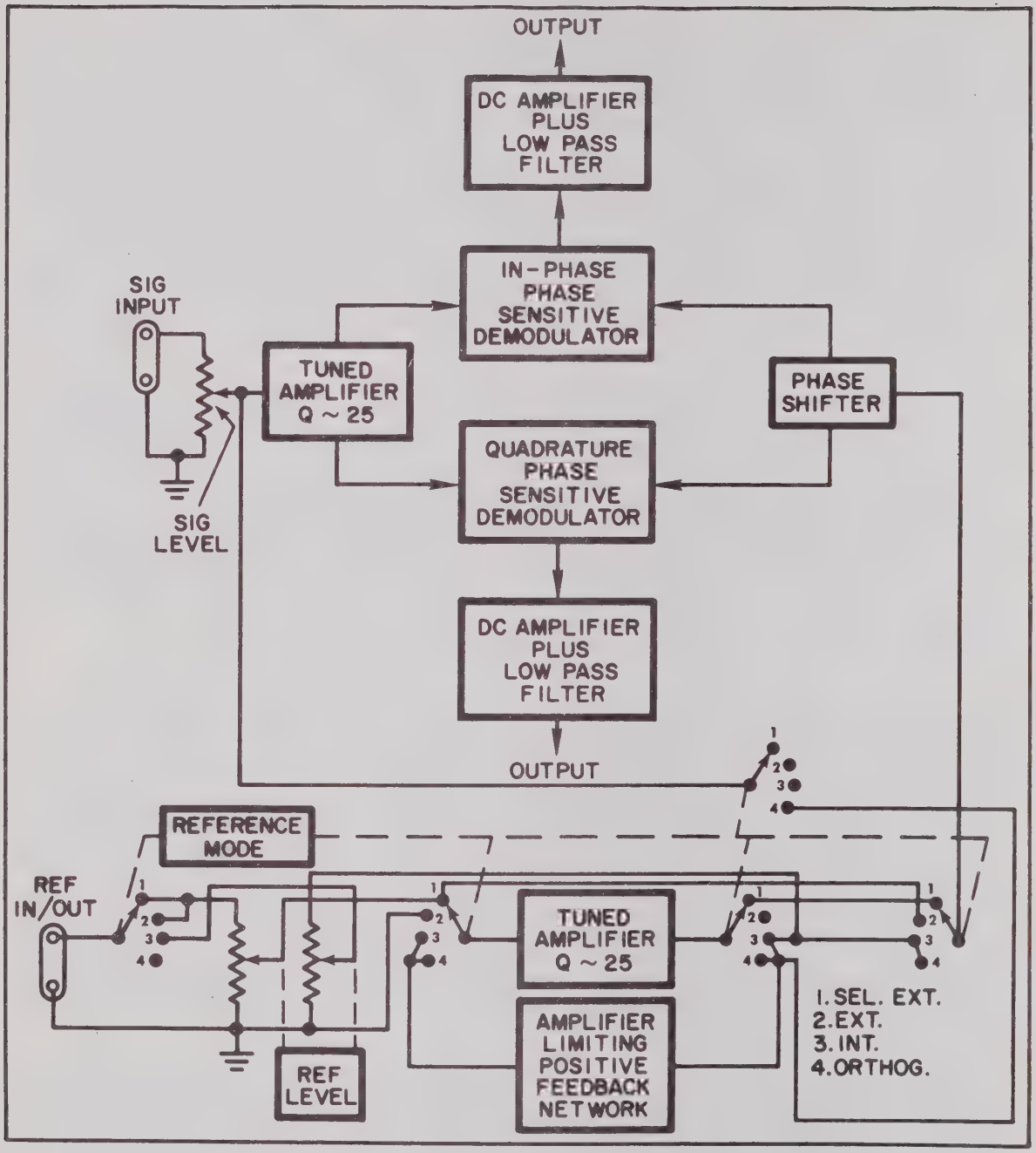

Figure III-1. BLOCK DIAGRAM OF MODEL JB-6

apply power and set the controls as follows:

SIGNAL LEVEL ---------- OFF
REF MODE ---------- INT
MONITOR SELECTOR ---------- I OUTPUT

Adjust the two ZERO controls (red knobs concentric with the RESPONSE TIME controls) so the meter pointers are exactly at zero. These adjustments should be made as accurately as possible, as an error here will incur an error in the quadrature adjustment.

3.3 REFERENCE CHANNEL

The operation of the reference channel depends on the mode being used. Consequently, the three available modes will be treated separately.

EXTERNAL

This mode is used when a sine wave of at least three but less than seven volts peak-to-peak amplitude is available for use as the reference voltage. (At this level the demodulator is insensitive to small changes in reference amplitude). If a reference waveform meeting these requirements is available it can be coupled into the instrument via the REFERENCE IN/OUT terminals located on the front panel. This input is single-ended, the red binding post being the "high" side and the black binding post being chassis ground. A resistance of 54 k ±5% (the REFERENCE LEVEL control) is internally connected directly across these terminals.

In this mode of operation the only adjustment required is to set the reference amplitude at the proper value. For this purpose an AC voltmeter or preferably an oscilloscope is required. With the instrument power on and the reference source connected to the REFERENCE IN/OUT terminals, the following instrument control settings are made:

REFERENCE MODE ---------- EXT
MONITOR SELECTOR ---------- REF

Connect the oscilloscope (or voltmeter) to the right-hand red MONITOR terminal and to chassis ground (the black terminal). Rotate the REFERENCE LEVEL control until the amplitude of the sine wave seen on the oscilloscope is more than three but less than seven volts peak-to-peak. Note the reading on the right-hand panel meter (MONITOR METER). This reading corresponds to the proper reference level for the instrument and may be used for checking or resetting the reference level. (NOTE: A slight flattening of the positive peak of the sine wave may be observed. This does not affect the operation of the instrument).

The reference channel is now set for operation in the EXT reference mode.

SELECTIVE EXTERNAL MODE

The use of this mode of operation is required in two different circumstances. The first is when the available reference is less than three volts peak-to-

peak. In this case, the gain of the reference channel tuned amplifier is sufficient to amplify a reference signal of at least 100 millivolts peak-to-peak to the required three-to-seven volts peak-to-peak level.

The second situation requiring the use of the selective external reference mode is when a nonsinusoidal reference waveform or a reference signal accompanied by an excessive amount of noise is used. This is explained as follows: In this reference mode (as well as in the other modes) the reference signal is passed through a phase shift network before being applied to the demodulator, which is essentially a double-pole double-throw reversing switch driven at the reference frequency by a square wave. The square wave is obtained by feeding the output of the phase shifter into a Schmitt trigger circuit. Certain non-sinusoidal waveforms applied to the input of the phase shifter will produce output waveforms which will result in improper triggering of the Schmitt and consequent improper operation of the demodulator. For this reason, if the reference waveform is not sinusoidal it should be passed through the reference channel tuned amplifier in order to make it more nearly sinusoidal by reducing its harmonic content. In general, this mode of operation allows a particular frequency to be selected out of a complex waveform and used as the reference frequency.

With the instrument power turned on and the reference source connected to the REFERENCE IN/OUT terminals, adjust the instrument controls as follows:

REFERENCE MODE ---------- SEL. EXT.
MONITOR SELECTOR ---------- REF.
FREQ. RANGE ---------- DESIRED REF. FREQ.
FREQUENCY ---------- DESIRED REF. FREQ.

Connect an oscilloscope to the MONITOR terminals (right-hand red binding post is "high" side, black is chassis ground). Adjust the FREQUENCY dial to maximize the amplitude of the sine wave which is displayed on the oscilloscope. Adjust the REFERENCE LEVEL control so that the amplitude of the maximum response so obtained is between three and seven volts peak-to-peak as measured by the scope. (A slight flattening of the positive peaks of the sine wave may be observed. This does not affect proper operation of the instrument.)

If the desired frequency component is a very small percentage of the peak amplitude of the reference waveform, it may not be possible to obtain a sine wave of the amplitude specified above due to the peak level exceeding the limits of the tuned amplifier. If this is the case, the only solution is, by means of external filtering, to reduce the amplitude of the undesired frequencies in the reference waveform before applying it to the input of the tuned amplifier.

Once a sinusoidal waveform within the above amplitude limits has been obtained at the MONITOR terminals, note the reading of the righthand panel meter (MONITOR METER). This reading corresponds to a proper reference level for the instrument and can be used for re-setting and checking.

The above adjustments having been carried out, the instrument is ready for operation in the SELECTIVE EXTERNAL reference mode.

INTERNAL MODE

In the INTERNAL REFERENCE mode, a positive feedback network is connected to the reference channel tuned amplifier, converting it to an oscillator operating at the frequency to which the channel is tuned. The proper voltage for operating the switching circuits in the demodulators is automatically provided by a limiting circuit incorporated in the feedback network. To examine the operation of the internal oscillator, make the following switch settings:

REFERENCE MODE	INT.
MONITOR SELECTOR	REF.
FREQ. RANGE	DESIRED REF. FREQ.
FREQUENCY	DESIRED REF. FREQ.

Connect an oscilloscope to the right-hand MONITOR terminal and chassis ground (black terminal). A sine wave with an amplitude between three and seven volts peak-to-peak should be seen on the oscilloscope, and the panel meter should deflect. If this is not the case, refer to INTERNAL OSCILLATOR ADJUSTMENT in the ALIGNMENT PROCEDURE and follow the alignment instructions therein.

If this adjustment is made at a frequency of 400 Hz, the reference level will remain within acceptable limits over the entire frequency range of the instrument.

The internal reference mode of operation is applicable when the signal source can be synchronized or triggered by an injected voltage. A sinusoidal voltage at the reference frequency is available for this purpose at the REFERENCE IN/OUT terminals. Maximum amplitude is approximately five volts peak-to-peak, and this can be attenuated by the REFERENCE LEVEL control. The impedance looking into the REFERENCE IN/OUT terminals varies with the switch setting. The maximum is 1.4 k ohms at the 0.5 position. (Note: the REFERENCE LEVEL switch does not affect either the voltage at the MONITOR terminals or the MONITOR METER indication in the REF. position of the MONITOR SELECTOR switch.)

3.4 SIGNAL CHANNEL

The SIGNAL INPUT is single-ended, the black binding post being at chassis ground. A 54 k ±5% resistor (the SIGNAL LEVEL control) is internally connected directly across these terminals. When dealing with low-level signals, it is important to avoid injecting spurious voltages generated by ground currents into the input circuit. In general, the best arrangement is to have only one ground connection between the signal source and the Lock-In Amplifier and to make this connection to the black SIGNAL INPUT binding post. In cases where large ground currents flow between the signal source and the Lock-In Amplifier chassis, other arrangements may be better. The best one in a given situation can be determined only by trial.

It is assumed here that the reference channel is set up and operating in the desired mode and at the correct frequency. With the SIGNAL LEVEL switch at OFF, connect the signal source to the SIGNAL INPUT terminals. Set the MONITOR SELECTOR switch at SIG. and turn the SIGNAL LEVEL control until a reading

is obtained on the MONITOR METER. If the reference circuit is operating in either INTERNAL or SELECTIVE EXTERNAL mode, maximize the meter reading by adjusting the FREQUENCY TRIM control. If the reference circuit is in EXTERNAL mode, adjust the FREQUENCY knob and FREQUENCY RANGE switch to approximately the signal frequency, then maximize the meter deflection by varying the FREQUENCY knob.

OPERATION OF X1 FREQUENCY RANGE

Those who are forced to operate at frequencies in this range should be aware of the behavior of tuned amplifiers at these frequencies. Their behavior is similar to that of a parallel RLC circuit with a Q of 25. The rise time (0 to 63%) of such a circuit whose resonant frequency is f_o is given by:

$$t_r = \frac{Q}{\pi f_o}$$

For a frequency of 1.5 Hz this gives a rise time of the order of five seconds. This sets the time lag between any change made in the input level to, or the center frequency of, the tuned amplifier and the resulting response. Furthermore, any transient which affects the tuned amplifier will set up a ringing response which will take a time of this order to decay. As a result tuning and level setting at very low frequencies often become a test of patience. If at all possible, at such frequencies it would be desirable to reduce the Q of the tuned amplifier, and to make up the lost gain by means of a low-pass preamplifier.

It will be noted that the internal noise in the Model JB-6 increases noticeably at the low-end of its frequency range. This is due to the well known 1/f component of the noise generated in transistors (and likewise in tubes). In general the noise figure of a transistor amplifier begins to deteriorate below about 100 Hz. The internal noise level of the Model JB-6 at the extreme low-end of its range is somewhat higher than at say 400 Hz. However, it will be observed that with a long filter time constant (e.g., 10 seconds) in use, the output noise is at an acceptable level. Since lock-in operation at these low frequencies always entails the use of time constants of this order, it is only noise output under such conditions that is meaningful. A careful check of the AC BALANCE ADJUSTMENT should be performed to make certain that mixer unbalance is not contributing to output fluctuations seen at low frequencies without filtering.

ORTHOG

To adjust the two orthogonal output signals to exactly 90° phase difference, set the controls as follows:

SIGNAL LEVEL	OFF
REFERENCE MODE	ORTHOG
MONITOR SELECTOR	Q OUTPUT
RESPONSE TIME	3 SECONDS

Adjust the ORTHOG control (red knob concentric with the SIG. LEVEL control)

so that the QUADRATURE meter is at zero. (Note: Before this adjustment is made, the user should be certain that the previously described zero adjustments have been accurately made.)

I GAIN

The gain of the in-phase channel should now be adjusted in order that the same maximum output can be obtained from either channel with appropriate adjustment of the phase control. To accomplish this task, apply the proper signal inputs to the unit. With the reference channel set up and operating in the desired mode and at the correct frequency, connect the output of the signal source to the SIGNAL INPUT terminals. Alternately, the input signal may be obtained from the internal oscillator when the unit is operating in the INT. reference mode. Simply connect the red IN/OUT terminal to the red SIGNAL INPUT terminal by means of a jumper wire. In any case, adjust the SIG. LEVEL control as required to obtain a reading on the MONITOR METER with the MONITOR SELECTOR set to I OUTPUT. Both the quadrature and in-phase RESPONSE TIME selectors should be set at three seconds. Adjust the FREQ. TRIM to maximize the indication on the meter. Rotate the PHASE control so as to maximize the indication on the QUADRATURE METER AND note the meter reading. Rotate the PHASE control to maximize the in-phase output appearing on the MONITOR METER. Adjust the I GAIN control (red knob concentric with REF. LEVEL control) to obtain the same maximum reading as previously noted on the QUADRATURE METER.

RESPONSE TIME

The time constants of the RC filters in the output amplifiers are determined by the settings of the two RESPONSE TIME switches. Internal capacitors provide response times of 0.001, 0.01, 0.1, 1.0, 3, and 10 seconds. Single-section or double-section filtering may be selected by the 6 dB, 12 dB PER OCTAVE switches associated with the two output channels.

A word about the choice of single or double-section RC filtering is in order here. Figures III-2A and III-2B respectively show single and double-section RC filters similar to those used in the Lock-In Amplifier. (The effect of the buffer in Figure III-2B is to isolate the two sections so that the second section does not load the first. In this instrument the DC amplifier plays the role of buffer.)

In comparing the two circuits we see that:

(1) For a given time constant (RC) the equivalent noise bandwidth of the double-section filter is ½ that of the single-section filter.

(2) For a given noise bandwidth the rise time of the double-section filter is about 23% less than that of the single-section filter.

When the instrument is used to drive a recorder, it is clear from the above that the use of double-section filtering is advantageous in providing a worthwhile decrease in response time for a given noise bandwidth.

In many applications the Lock-In Amplifier is used as a component in a closed

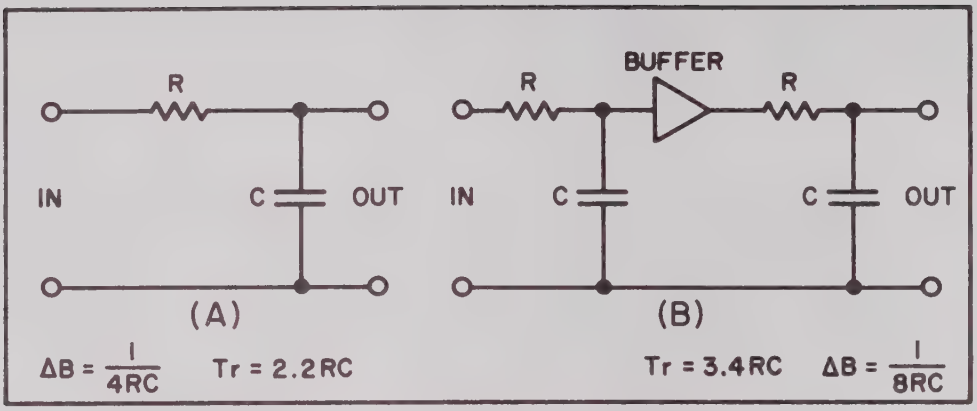

Figure III-2. TIME CONSTANT FILTERS

"servo loop". One criterion of stability (freedom from oscillation) of such a loop is that at no frequency shall the open loop gain roll-off as fast as 12 dB/octave. In such applications the 12 dB/octave position cannot be used and it is for this reason that the 6 dB/octave position has been provided.

USE OF EXTERNAL CAPACITORS

Two standard octal sockets are provided on the rear panel of the instrument to allow those needing filtering time constants longer than those available internally to obtain them by making use of external capacitors. When the RESPONSE TIME switches are in the EXT. position, the time constants are determined by capacitors wired to these sockets in either of the two ways shown in Figure III-3. The values of the capacitors for a given time constant are as follows:

Capacitance	Working Voltage	Type
C_1 = 12 μF/second	15	non-polarized
C_2 = 6 μF/second	15	polarized
C_3 = 24 μF/second	15	polarized

For example, if a 30 second time constant is desired, the following capacitors are required:

$C_1 = 12 \times 30 = 360$ μF
$C_2 = 6 \times 30 = 180$ μF
$C_3 = 24 \times 30 = 720$ μF

Thus, if the arrangement of Figure III-3A were to be used, the capacitors required would be 1 @ 360 μF, and 2 @ 180 μF in each output channel. If the arrangement of Figure III-3B were to be used, 2 @ 720 μF would be needed. The advantage of the latter arrangement is that it allows the use of all polarized capacitors which, in general, are available in higher capacities than the non-polarized variety.

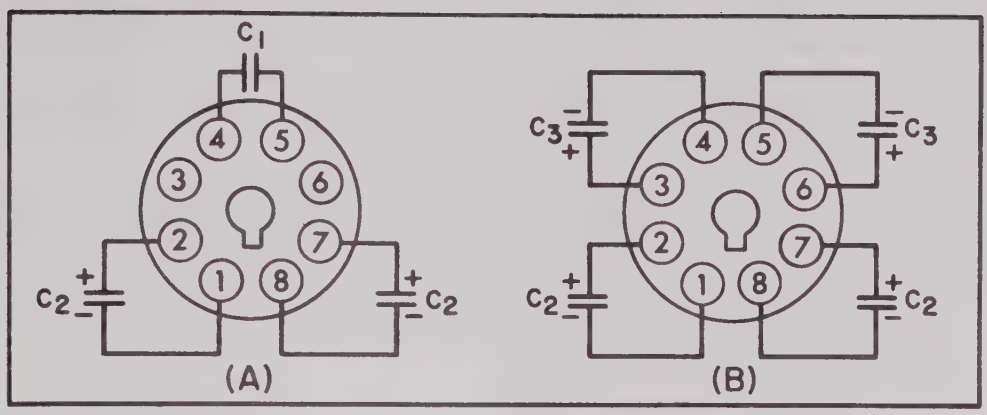

Figure III-3. REAR PANEL SOCKETS

The performance of the instrument can be seriously impaired by leakage in these capacitors. For this reason only those types of capacitors listed below should be used.

POLARIZED: tantalum electrolytic.
NON-POLARIZED: tantalum electrolytic, paper, oiled paper, polystyrene film, mylar film.

With either of the arrangements shown in Figure III-3, either 6 or 12 dB per octave filtering is available, depending on the position of the 6 dB, 12 dB/OCTAVE switch. If only 6 dB/octave is required, omit C_1 in Figure III-3A or C_3 in Figure III-3B.

PHASE ADJUSTMENT

In order that two-phase measurements have meaning, it is necessary that the phase adjustment be made in some systematic way. If the reference information and the signal information are extracted from different points in a network such that there is a phase difference between them, the reference voltage may be used to establish the phase adjustment. This can be done by feeding reference voltage into the signal circuit, and adjusting the PHASE control to set one of the panel meters exactly at zero and the other at maximum. If the phase angle between signal and reference is variable with time, the PHASE control may be adjusted to set one meter to zero at a particular moment, and phase variations thereafter will affect the two meter deflections.

FINAL ADJUSTMENT

The adjustments described above having been completed, the instrument is essentially ready for operation. All that remains is to set the RESPONSE TIME controls for the desired output bandwidth and to adjust the SIGNAL LEVEL control for the desired output level. However, the latter adjustment must be made with care so as not to produce an overload condition.

Overloading can occur in all or any of the three parts of the instrument--the signal tuned amplifier, the demodulator (or mixer), and the output DC amplifier. Overloading at any of these points will result in nonlinearity and an increase in the noise level due to cross-modulation (noise beating with noise). A systematic procedure for checking for an overload condition is outlined below.

(1) With an input signal applied and the MONITOR SELECTOR in the SIG position, connect an oscilloscope to the MONITOR terminals. If the scope shows that the waveform at the output of the signal channel tuned amplifier is being clipped, the input signal level must be reduced. If noise peaks are being clipped and the signal is very weak, it is desirable to introduce a filter ahead of the Lock-In to reduce the ratio of noise-to-signal.

(2) If the unit is operating in the INT reference mode, this step may be omitted since in this mode the correct reference voltage is applied to the demodulator automatically. However, in either the EXT or SEL EXT reference modes of operation, the MONITOR SELECTOR should be put in the REF position and an oscilloscope attached to the right-hand red MONITOR terminal and ground. The reference waveform should be a reasonable approximation to a sine wave whose peak-to-peak amplitude is at least three but less than seven volts and whose half cycle time intervals are equal.

(3) If the mixer is over-driven, noise signals at its input will contribute to its output which would not otherwise do so. In general, to obtain maximum possible output from the instrument in a given situation, the SIGNAL LEVEL control should be advanced until the OVERLOAD indicator glows and then backed off one step; the instrument then being operated with the SIGNAL LEVEL control in this position. In any case, as long as the OVERLOAD indicator does not glow one can be content that the mixer is not being over-driven. The OVERLOAD indicator circuit has been designed so that the light will come on before a serious overload condition exists.

Each channel should be checked separately. With the MONITOR SELECTOR set to I OUTPUT and the RESPONSE TIME set as required to eliminate extreme fluctuations of the meter, adjust the PHASE control to maximize the meter reading. Increase and then decrease the SIGNAL LEVEL control one step from its nominal setting. The meter reading should change in the exact proportion as indicated by the SIG LEVEL CONTROL. If it does not, there is an overload condition existing which can be remedied by reducing the signal input level or the noise-to-signal ratio, or both. Rotate the PHASE control to maximize the reading on the QUADRATURE METER in order to check for overload in this channel by the same procedure given above.

3.5 RECORDER OPERATION

Separate recorder output terminals for both the quadrature and in-phase outputs are located at the rear of the unit. Note, however, that signals are <u>not</u> available at either of these outputs when the MONITOR SELECTOR is in the SIG or REF positions. The following procedure will be written with re-

spect to the in-phase output but the same procedure is applicable for the quadrature output.

If a galvanometer type recorder is to be used, it should be connected to the two red I OUTPUT binding posts. The Lock-In Amplifier will drive any such recorder of 1 ma sensitivity with a coil resistance of less than 2 k.

Two modes of operation are provided for such recorders: "Left-hand zero" operation and "center zero" operation. A toggle switch located on the rear of the instrument selects the desired mode, and a screwdriver adjust potentiometer, also located on the back of the instrument, allows the recorder to be adjusted to agree with the panel meter.

(1) Left-Hand Zero Operation

In this mode of operation, with the MONITOR SELECTOR in the I OUTPUT position, the recorder pen lies at the left-hand edge of the chart when the panel meter reads zero and at the right-hand edge when the panel meter reads full scale. If such operation is desired, the set-up is as follows: First set the recorder pen at the left-hand chart edge by means of the mechanical zero-adjuster on the recorder. Set the MONITOR SELECTOR switch to the I OUTPUT position and connect the recorder to the two red OUTPUT terminals. Adjust the ZERO control on the instrument so that the panel meter reads zero. Put the toggle switch on the rear of the instrument in the 1 ma position. Apply an input signal to the instrument and adjust its amplitude so that the panel meter reads full scale. (If the recorder does not deflect in the same direction as the panel meter, reverse its connections at the OUTPUT terminals.) Rotate the F.S. ADJUST pot (also on the rear of the instrument) until the recorder also reads full scale.

(2) Center Zero Operation

In this mode of operation the recorder pen lies at the center of the chart when the panel meter reads zero, and at the left or right edge of the chart when the panel meter reads negative or positive full scale respectively. If such operation is desired, set the recorder pen to the center of the chart by means of the mechanical zero-adjuster on the recorder. Set the toggle switch on the rear of the instrument to the ½ ma position and proceed as outlined in the preceding section.

OPERATION WITH ESTERLINE-ANGUS RECTILINEAR RECORDER

This is a 1 milliamp full scale recorder with an internal resistance of about 6 k. It may be used with these instruments but not quite as conveniently as the 1.5 k type.

(1) Center Zero Operation

Follow the instructions for CENTER ZERO OPERATION above with the exception that the rear panel toggle switch must be placed in the 1 ma position.

(2) Left-Hand Zero Operation

Use the mechanical zero adjustment on the recorder to set the pen at the left-hand edge of the chart at zero input. With the MONITOR SELECTOR switch in either the I OUTPUT or Q OUTPUT position (only one output can be obtained by this method), plug the recorder into the two red MONITOR terminals. When the recorder reads full scale the panel meter will read somewhat off-scale. (This will not damage the panel meter.)

There is no way to make the panel meter track the recorder under these conditions except by changing the meter resistors inside the Lock-In Amplifier.

RECORDER OPERATION, SERVO-TYPE

Recorders of this type are voltage rather than current measuring devices. Thus it is necessary to convert the current output of the Lock-In Amplifier into a voltage output whose range is suited to the recorder being used. These recorders are available either with single-ended (one input terminal grounded) or push-pull (floating) inputs. The latter are somewhat more compatible with these instruments.

(1) Push-Pull Input Types

When the panel meters (in the I OUTPUT position of the MONITOR SELECTOR switch) read zero, the two red OUTPUT terminals are at the same potential (-6 V relative to chassis ground). A push-pull input recorder thus must be able to withstand a -6 V common mode level at its input terminals (see recorder instruction manual). If this voltage (-6 V) exceeds the common mode rating of the recorder it would be best to ground one of its input terminals and treat it as a single-ended recorder (see following section). If the recorder has this degree of common mode rejection, proceed as follows: connect a resistor (preferably wirewound) across the input terminals of the recorder whose resistance R, in ohms is given by:

$$10^{-3} R = E_{FS}$$

where E_{FS} is the voltage required at the input to the recorder to obtain a full scale deflection of the pen. If the recorder is now connected to the OUTPUT terminals, the set-up instructions given in the preceding section for galvanometer type recorders may be followed exactly. This will work with any recorder of this type having a full scale sensitivity of 2 V or less.

(2) Single-Ended Input Types

In most cases it will be possible to simply "float" the recorder on the Lock-In Amplifier output. To do this, connect the ground terminal of the recorder to one of the OUTPUT terminals, and the recor-

der input terminal to the other. THERE MUST BE NO CONNECTION BETWEEN THE RECORDER CHASSIS AND THE LOCK-IN AMPLIFIER CHASSIS. If the recorder has a three-wire line cord, an isolating adapter must be used. Connect a resistor whose value is obtained from the equation in the preceding section across the recorder input terminals and proceed as described in that section.

With some recorders using 60 Hz choppers, trouble may be encountered under these conditions due to 60 Hz pick-up. Usually this can be cured by connecting a one microfarad or larger capacitor between the Lock-In Amplifier chassis and the recorder chassis. (If an electrolytic capacitor is used, observe polarity; recorder chassis is at -6 V relative to the Lock-In Amplifier chassis). If this fails to clear up the trouble (also try reversing the recorder-line plug-in socket), then the procedure outlined below must be used.

Should "floating" operation not be possible then the following technique must be employed (see Figure III-4).

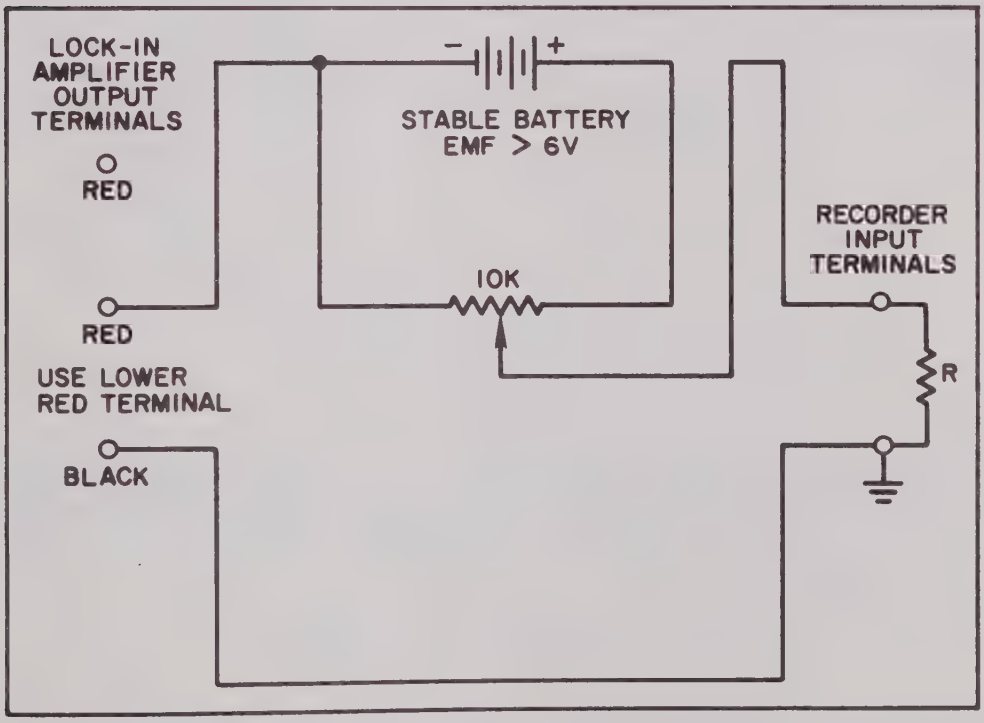

Figure III-4. USING EXTERNAL BATTERY TO BUCK OUT QUIESENT OUTPUT LEVEL

NOTE: Use lower red output terminal. In this case the 1 ma/switch will not affect recorder operation.

The 10 k potentiometer is adjusted until the panel meter indicates zero when the recorder also indicates zero. (Left-hand, right-hand or center zero may be used for recorder). R is then adjusted so that when the panel meter reads full scale, the recorder also indicates full scale. The value of R for center zero operation will be different (about ½) from that required for left or right-hand zero operation. It is recommended that mercury cells be used to establish the 6 V "bucking potential".

Some single-ended recorders have considerable "zero suppression" built-in. This is usually expressed as a multiple of full scale (e.g. 10 x full scale). If sufficient zero suppression is available, the somewhat simpler arrangement shown below can be used (Figure III-5).

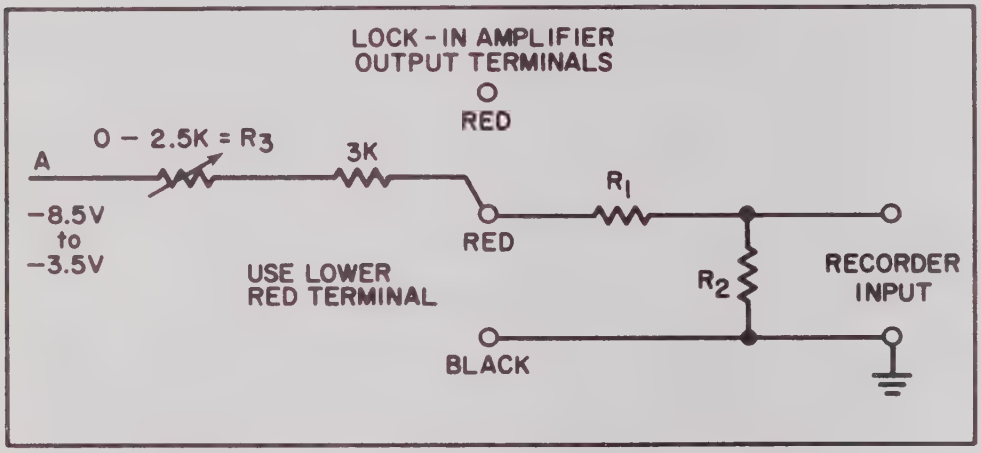

Figure III-5. USING RECORDER ZERO SUPPRESSION TO BUCK OUT QUIESCENT OUTPUT LEVEL

Let E_{ZS} be the maximum recorder zero suppression and E_{FS} be the recorder full scale voltage. A voltage divider, consisting of R_1, R_2 and the 3 k and 2.5 k resistors inside the Lock-In is set up at its output. The DC level at the point A in Figure III-5 is -6 V when the panel meter indicates zero. If the resulting DC level at the recorder is to be within its range of zero suppression we must have.

$$6 \times \frac{R_2}{R_3 + 3\text{ k} + R_1 + R_2} = 6\,\lambda = E_{ZS} \quad \text{where:} \quad \lambda = \frac{R_2}{R_3 + 3\text{ k} + R_1 + R_2}$$

If full scale on the panel meter is to correspond to full scale on the recorder we must have:

$$2.5\ \lambda = E_{FS}$$

$$\text{i.e. } \lambda = \frac{E_{FS}}{2.5}$$

and hence:

$$\frac{6}{2.5} = \frac{E_{ZS}}{E_{FS}}$$

thus, if the zero suppression built into the recorder is 6/2.5 = 2.4 times full scale or better, it can be used in this way. R_3, which is the RECORDER ADJUST potentiometer located on the back of the Lock-In, may be used for fine adjustment of full scale.

3.6 TO DETECT SIGNALS AT HARMONICS OF SOME BASIC REFERENCE FREQUENCY

In some Lock-In Amplifier applications the signal appears at a harmonic of the basic reference frequency. In such a case the Lock-In Amplifier must be operated at this harmonic frequency. The JB-6 is ideally suited to this sort of operation because of its continuously tunable reference channel amplifier. In general, the reference signal (assumed to be sinusoidal) is fed into a simple harmonic generator, the desired harmonic being selected by means of the tuned amplifier.

If even (2nd and higher) harmonics are of interest the following harmonic generator is useful:

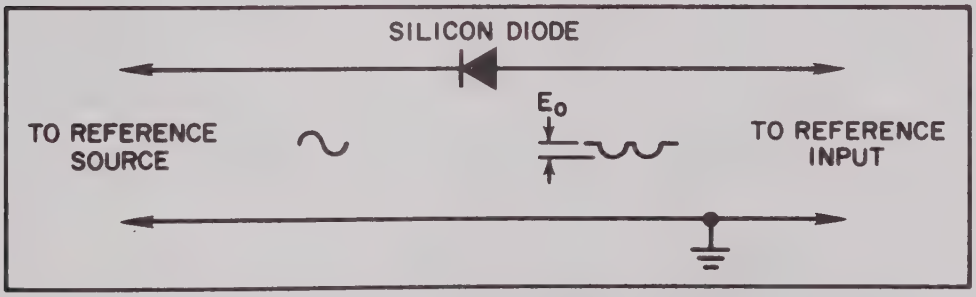

Figure III-6. EVEN-HARMONIC GENERATOR

The amplitude of the reference sine wave should be several volts peak to obtain efficient rectification.

The Fourier Series of an ideal waveform of this type is:

$$E(t) = E_o\left[\frac{1}{\pi} + \frac{1}{2}\sin\omega t - \frac{2}{\pi}\sum_{k=2}^{\infty}\frac{\cos k\omega t}{k^2 - 1}\right] \text{ (k even)}$$

where E(t) is the output waveform of the half wave rectifier and E_o is the peak value of the input voltage. Apart from the fundamental, the output contains only even harmonics.

For operation in the SEL. EXT. mode a minimum level (of the desired harmonic) of 100 millivolts peak-to-peak is required at the reference input terminals, i.e. we must have:

$$2A_2 \geq 100 \text{ mV.} \quad (A_2 = \text{peak amplitude of second harmonic}).$$

$$\text{i.e.} \quad \frac{4E_o}{3\pi} \geq 100 \text{ mV.}$$

$$E_o \geq \frac{100 \times 3\pi}{4} \simeq 235 \text{ mV}$$

Since this is below the minimum value for efficient rectification by a silicon diode it is clear that any reference voltage large enough to produce the output waveform of Figure III-6 will be adequate to drive the Lock-In Amplifier.

For second harmonic operation, simply feed the reference signal to the Lock-In via a diode as shown in Figure III-6. Set the FREQUENCY dial and FREQUENCY RANGE switch to the second harmonic of the reference frequency and proceed according to the instructions given above for operation in the SELECTIVE EXTERNAL reference mode.

Operation on even harmonics higher than the second is possible. The following considerations should be understood before such operation is attempted.

The reference channel tuned amplifier at full gain "1" can withstand an input of at least 1 V peak-to-peak and still maintain its normal selectivity characteristic. In order to assure proper operation the maximum instantaneous peak input voltage must be kept below this level. (Of course for settings of the REFERENCE LEVEL control other than "1" this limiting value is proportionately higher). If a high order harmonic is used the level of the harmonic of interest will be considerably lower than the maximum instantaneous peak input level (E_o). If we assign a maximum value of 1 to E_o, the component parts of the rectified wave are:

fundamental	1.0 V peak-to-peak
2nd harmonic	.424 V " " "
4th harmonic	.085 V " " "
6th harmonic	.036 V " " "

Thus, operation at the fourth harmonic should be possible, but at the sixth and higher harmonics there is not enough voltage for operation of the reference circuit.

For the sixth and higher even harmonics, the circuit of Figure III-7 can be used.

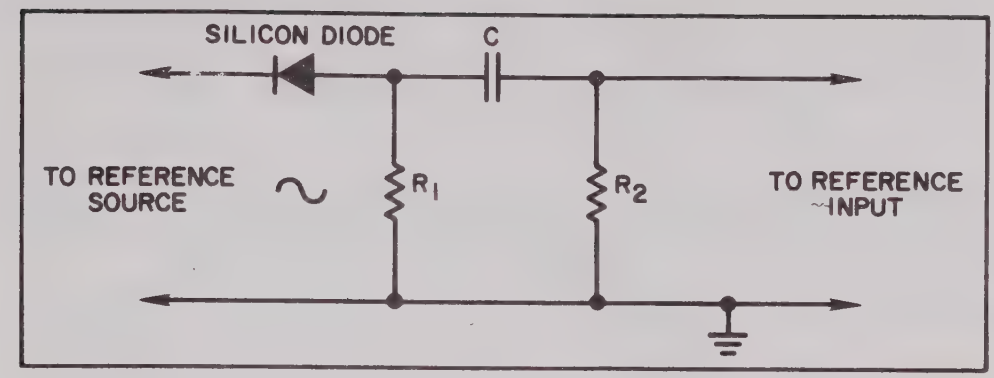

Figure III-7. EVEN HARMONIC GENERATOR FOR HIGHER HARMONICS

R_2 and C constitute a high-pass filter whose effect is to reduce the level of the lower order harmonics. A good choice for R_2C is a value such that

$$\omega_n = \frac{1}{R_2 C}$$

where ω_n is the angular frequency of the desired harmonic. Of course more elaborate preselection methods may be used.

In any case the Lock-In is set to the frequency of the desired harmonic and set up as outlined in the SELECTIVE EXTERNAL section of OPERATING INSTRUCTIONS in this manual.

If odd (3rd and higher) harmonic operation is desired the following circuit can be used (Figure III-8).

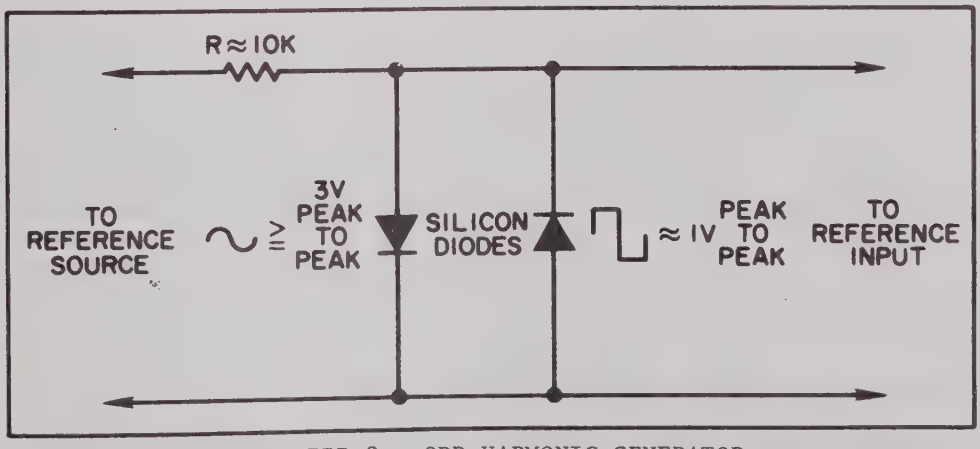

Figure III-8. ODD HARMONIC GENERATOR

The resulting waveform has a harmonic structure given closely by:

$$E(t) = \frac{4E_o}{\pi} \sum_{k=0}^{\infty} (-1)^k \frac{\cos (2k + 1)\, \omega t}{2k + 1}$$

where E_o is about ½ volt for silicon diodes without bias voltage. Using an argument similar to that of the preceding section it turns out that this arrangement will permit operation up to the 5th harmonic.

If operation at higher odd harmonics is desired the following circuit may be used.

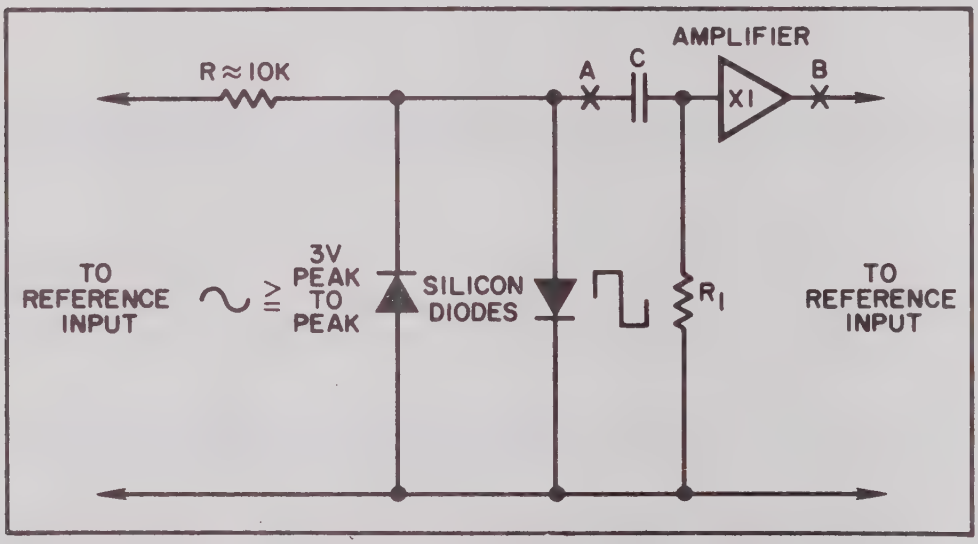

Figure III-9. ODD HARMONIC GENERATOR FOR HIGHER HARMONICS

If $R_1C = \frac{1}{\omega_n}$ the voltage gain from A to B at a frequency ω_n will be approximately 0.7. At frequencies ω, below ω_n the gain is roughly proportional to ω. The amplitude of the harmonics in the input waveform is proportional to $1/\omega$. Therefore up to ω_n the various odd harmonics appearing at B are all about the same amplitude. If ω_n is chosen to be the highest harmonic of interest, then operation at all odd harmonics below this will be possible.

In any case the Lock-In is tuned to the haromic of interest and set up according to the procedure in the SELECTIVE EXTERNAL section of OPERATING INSTRUCTIONS in this manual.

3.7 ABBREVIATED OPERATING INSTRUCTIONS

The following abbreviated operating instructions may prove helpful after the user has become familiar with the use of the instrument.

PRELIMINARY ZEROING ADJUSTMENTS

(1) With POWER Switch in OFF position, check mechanical meter zero and, if necessary, adjust mechanical zeroing screws until meters read zero.

(2) Turn POWER on.

(3) Set: SIGNAL LEVEL ---------- OFF
REF. MODE ---------- INT.
MONITOR SELECTOR ------ I OUTPUT
(2) RESPONSE TIME --------- OFF
(Both)

(4) Adjust red ZERO controls such that meters read zero.

REFERENCE CHANNEL

The three modes are described separately.

EXTERNAL

(1) The external reference signal must be at least three but less than seven volts peak-to-peak. The wave shape should be a well defined sinusoidal wave.

(2) Set: REF. LEVEL ---------- OFF
REF. MODE ---------- EXT.
MONITOR SELECTOR ------ REF.

(3) Connect external reference signal to REF. IN/OUT terminals.

(4) Connect an oscilloscope or an AC VTVM between the right monitor terminal and ground.

(5) Rotate the REF. LEVEL control until the voltage appearing at the monitor terminal is at least three but less than seven volts peak-to-peak.

(6) Note the reading on the MONITOR METER. This reading may be used to recheck the reference level without using the scope or VTVM.

SELECTIVE EXTERNAL

(1) The external reference should be at least 100 millivolts peak-to-peak.

(2) Set: REF. LEVEL ---------- OFF
REF. MODE ---------- SEL. EXT.
MONITOR SELECTOR ------ REF.
FREQ. RANGE SWITCH ---- DESIRED REF. FREQ.
FREQ. DIAL ---------- DESIRED REF. FREQ.

(3) Connect the external reference signal to REF. IN/OUT terminals.

(4) Connect an oscilloscope or an AC VTVM between right monitor terminal and ground.

(5) Rotate the REF. LEVEL control until a signal appears on the scope or VTVM.

(6) Adjust the FREQUENCY dial until the signal on the scope or VTVM is at a maximum.

(7) Adjust the REF. LEVEL control until the signal appearing at the monitor terminal reads at least three but less than seven volts peak-to-peak.

(8) Note the reading on the MONITOR METER.

INTERNAL MODE

(1) Set:
REF. LEVEL ---------- 1.0
REF. MODE ---------- INT.
MONITOR SELECTOR ---------- REF.
FREQ. RANGE SWITCH -------- DESIRED REF. FREQ.
FREQ. DIAL ---------- DESIRED REF. FREQ.

(2) Connect an oscilloscope or an AC VTVM between the right monitor terminal and ground.

(3) The voltage appearing between the terminals should be in the range of three-to-seven volts peak-to-peak. If the voltage is not within this range, an internal oscillator adjustment is required.

(4) The internal reference can now be used at the voltage level obtained above or attenuated by adjusting the REF. LEVEL control to trigger or synchronize the signal source.

SIGNAL CHANNEL

(1) Set:
SIGNAL LEVEL ---------- OFF
MONITOR SELECTOR ---------- SIG.

(2) Apply the input signal. Rotate the SIGNAL LEVEL control clockwise until a reading is observed on the MONITOR METER.

(3) When operating in the EXT. reference mode, adjust the frequency dial and the FREQ. TRIM to maximize the deflection on the MONITOR METER. When operating in either the INT. or the SEL. EXT. reference modes, adjust only the FREQ. TRIM to maximize the deflection on the MONITOR METER.

ORTHOGONALITY

(1) Set the front panel controls as follows:

REFERENCE MODE ---------- INT.
MONITOR SELECTOR ---------- I OUTPUT
SIGNAL LEVEL ---------- OFF
FREQUENCY ---------- INTENDED OPERATING FREQUENCY

(2) Adjust the two ZERO controls (red knobs concentric with the RESPONSE TIME controls) such that the two meter pointers are exactly at zero. These adjustments should be made as accurately as possible, as an error here will incur an error in the Quadrature Adjustment.

(3) Jumper the red REF. IN/OUT binding post to the red SIG. INPUT binding post.

(4) Set the front panel controls as follows:

MONITOR SELECTOR ---------- SIG.
SIGNAL LEVEL and REFERENCE LEVEL --- Adjust for near full scale indication on the MONITOR METER.

(5) Adjust the FREQ. TRIM control for maximum indication on the MONITOR METER.

(6) Set the front panel controls as follows:

SIGNAL LEVEL ---------- OFF
REFERENCE MODE ---------- ORTHOG.
MONITOR SELECTOR ---------- Q OUTPUT

(7) Adjust the ORTHOG. control (red inner knob concentric with the SIG. LEVEL control) for an indication of zero on the QUADRATURE METER.

GAIN

(1) The gain of the in-phase channel should now be adjusted so that the same maximum output is obtained from both channels.

(2) Set: MONITOR SELECTOR ---------- I OUTPUT
REFERENCE MODE ---------- INT.
RESPONSE TIME ---------- 3 SECONDS (BOTH CHANNELS)
Sig. Level ——— for a Monitor Meter Reading

(3) With the proper input signal applied, rotate the PHASE control such that the QUADRATURE METER indicates maximum. Note the meter reading.

(4) Rotate the PHASE control until the MONITOR METER indicates maximum.

(5) Rotate the I GAIN control until the MONITOR METER reads the same as the maximum level noted in step 3 above.

(6) Repeat steps 3, 4, and 5 to ascertain that the gain of both channels is identical.

SECTION IV
CIRCUIT DESCRIPTION

4.1 INTRODUCTION

The various circuit elements that go together to make up this instrument are assembled on six plug-in printed circuit boards and one printed circuit board mounted on the front panel. The different boards are identified as follows: (the identification numbers listed below appear on the printed wiring side of the boards).

CIRCUIT	IDENTIFICATION NO.
SIGNAL CHANNEL TUNED AMPLIFIER	S1205
REFERENCE CHANNEL TUNED AMPLIFIER	R1206
MIXER-DC AMPLIFIER (IN-PHASE)	M1207I
MIXER-DC AMPLIFIER (QUADRATURE)	M1207Q
PHASE SHIFTER & VOLTMETER	PS0112A
POWER SUPPLY	P0114

Access to the plug-in boards may be had by removing the back cover of the instrument. They are located as shown in Figure IV-1, a top view of the instrument with the cover removed.

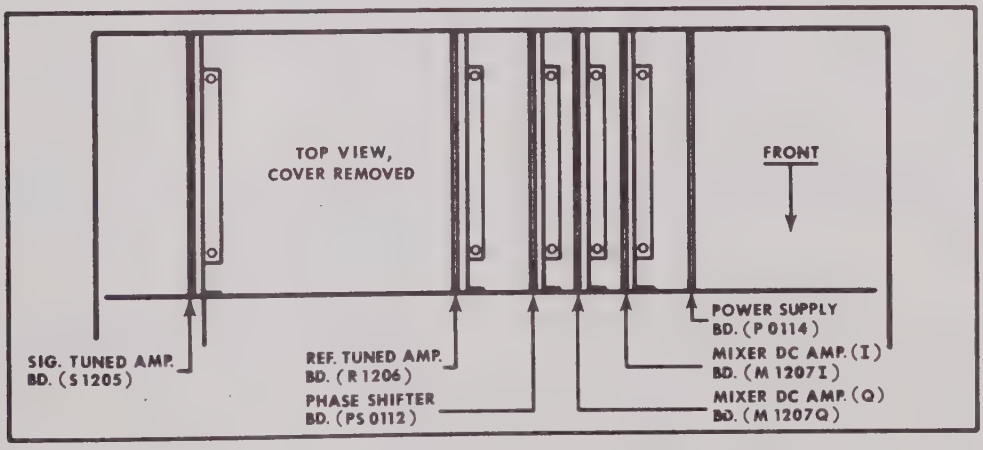

Figure IV-1. LOCATION OF CIRCUIT BOARDS

The circuitry will be described board by board to assist those with the task of trouble-shooting the unit and those users who wish to understand the principles of its operation.

4.2 SIGNAL CHANNEL AMPLIFIER (Board No. S1205)

The tuned amplifier in the signal circuit is based on the use of RC phase shift circuits. Figure IV-2 is a skeleton diagram of the tuning circuit of

the amplifier, and Figure IV-3 is a vector diagram illustrating its operation. Each phase shift circuit operates at such a frequency that its phase shift is 45°, and its output voltage or current is 70% of the input voltage or current. S_1 is a junction point at which the currents corresponding to E_1 and E_3 are summed, producing E_4. E_4 in turn is phase shifted, and the resulting E_5 has the same amplitude as E_2, but is 90° different in phase, as the vector diagram shows. E_2 and E_5 are passed through isolating amplifiers to the junction point S_2, where they are added. The resulting voltage, E_6, is in phase with the input voltage E_1. Two other isolating amplifiers, one of which is also a phase inverter, subtract E_2 from E_5, and the result, E_7 is in quadrature with E_1. It is easily shown (by plotting vector diagrams) that the output voltage E_6 is reduced in amplitude if the frequency is either increased or decreased from the amplitude at resonance and that the phase of E_6 shifts in the opposite direction from that of E_1 at frequencies above or below resonance. However, if the behavior of this circuit is to duplicate the behavior of an RLC tuned circuit exactly, a further requirement is that the output approach zero as the frequency approaches either zero of infinity. From Figure IV-2 it is clear that since both E_2 and E_5 approach zero at high frequencies due to the shunting effect of C_1 and C_2, and since $E_6 = E_2 + E_5$, the output approaches zero at high frequencies. At very low frequencies C_1 and C_2 have no effect, and we have:

$$E_2 = E_1$$
$$E_5 = -E_1$$
$$E_6 = E_2 + E_5 = E_1 - E_1 = 0$$

and again there is no output. This result depends on the gain between E_2 and E_3 being exactly -2. The LOW FREQUENCY BALANCE rheostat on the circuit board provides for adjustment to this value.

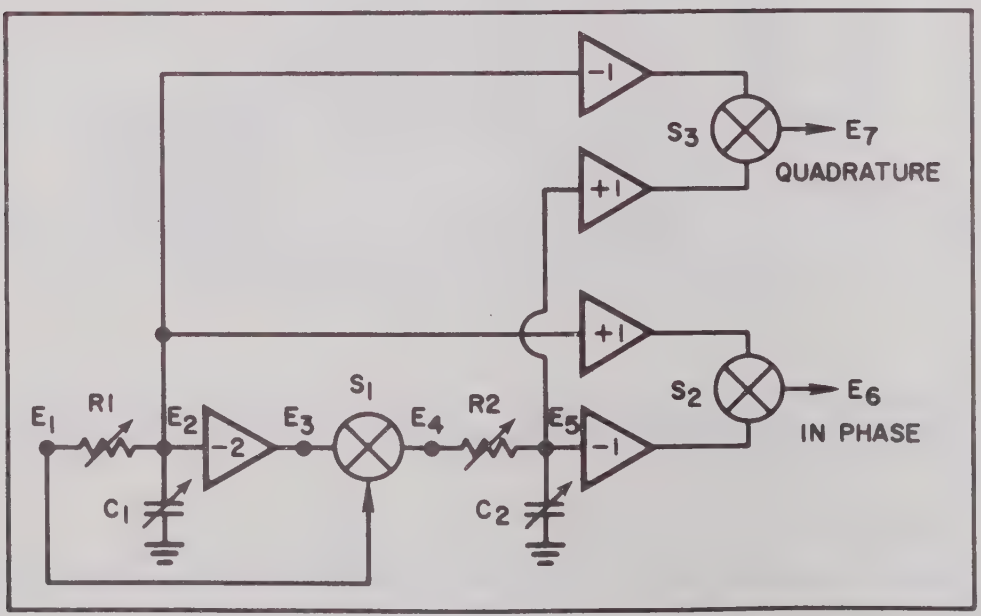

Figure IV-2. SIMPLIFIED BLOCK DIAGRAM OF SIGNAL TUNED AMPLIFIER

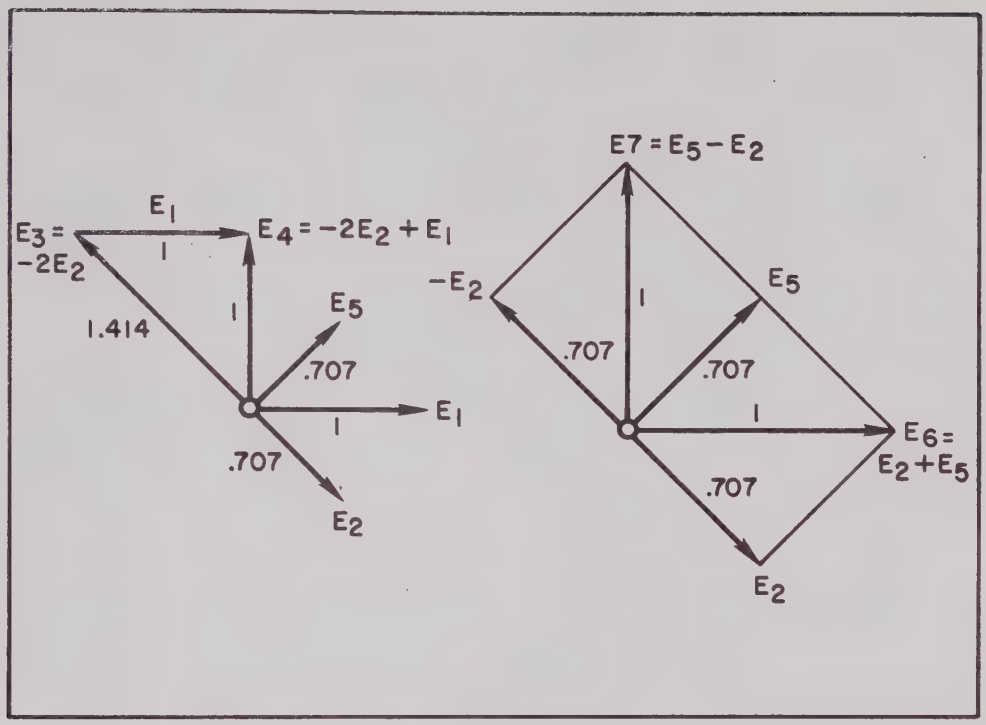

Figure IV-3. VECTOR DIAGRAMS OF SIGNALS IN THE SIGNAL TUNED AMPLIFIER

Thus, the circuit described above satisfies the tests, and is equivalent to the RLC tuned circuit; however its Q is only ½, a value which is too low to be useful. To raise the Q to the desired value of 25, positive feedback is provided, as illustrated in Figure IV-4.

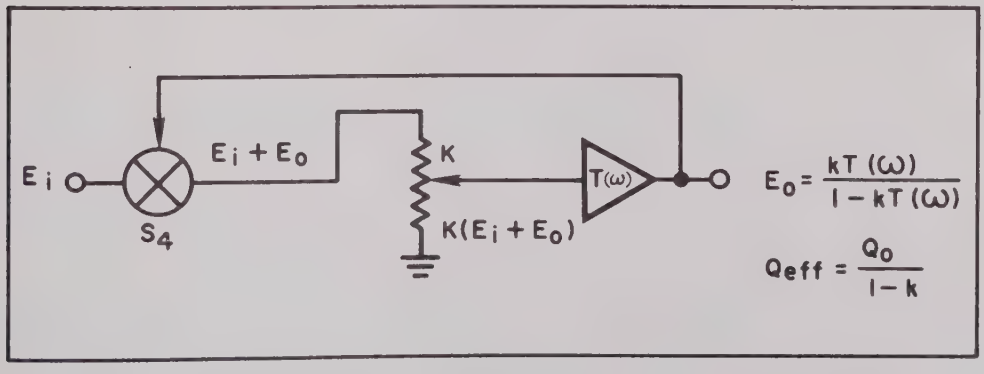

Figure IV-4. Q MULTIPLICATION IN THE SIGNAL TUNED AMPLIFIER

In the diagram, E_o is fed back and added to E_i at the summing point S_4. A fraction k of the sum is then amplified by the tuned amplifier described above, represented on the diagram by T (ω). Both the gain and the Q are controlled by k, and when the Q is 25, the gain is 49. In general, at any value of k the gain is approximately twice the Q value.

The quadrature output of the signal channel amplifier can be adjusted to a phase difference of exactly 90° from the in-phase output by use of the ORTHOGONALITY control. This is accomplished by adding a small amount of in-phase voltage, of either polarity, to the quadrature voltage as illustrated in the elementary vector diagram of Figure IV-5. Referring now to the schematic of the signal channel board, the transistor Q115 generates the push-pull in-phase voltage which appears at the terminals 01 and 02. The ORTHOG control is connected between these terminals. If it is adjusted either way from the center position, it picks-off a small in-phase voltage at either 0° or 180°, as required, which is added to the quadrature voltage at the base of transistor Q118. This transistor drives Q119, and Q119 develops the quadrature push-pull output voltage at terminals 03 and 04.

To recognize the condition of orthogonality, use is made of the fact that if signal and reference voltages at a demodulator are exactly orthogonal, the output is zero. This is done in a very simple way by using the internal reference oscillator as both reference source and signal source. The quadrature output of the signal amplifier is then at 90° from the reference voltage, and the ORTHOG control is adjusted to make the output of the quadrature demodulator exactly zero.

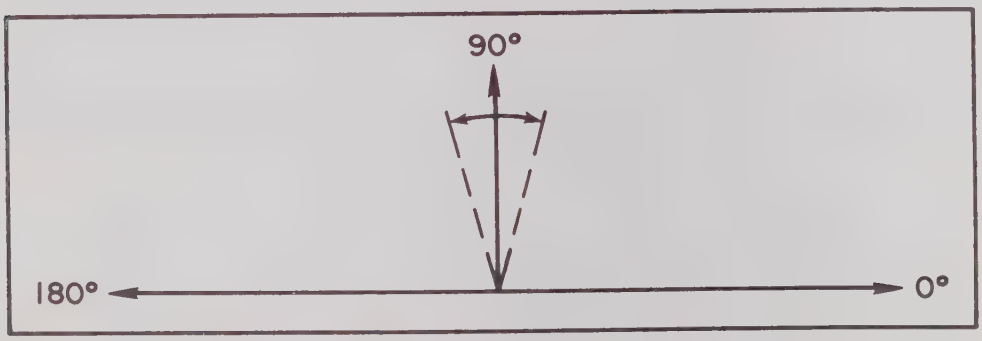

Figure IV-5. ORTHOGONALITY VECTOR

4.3 REFERENCE CHANNEL AMPLIFIER (Circuit Board No. R1206)

In the reference channel amplifier, the tuning circuit and the Q multiplying circuit are identical with the corresponding portions of the signal channel amplifier except for some small changes in resistor values and a higher supply voltage (24 volts instead of 20 volts). At the single-ended output of the amplifier there is a feedback network incorporating two diodes for limiting the oscillation amplitude when the amplifier is used as an oscillator to generate the reference voltage. Transistor Q216 provides the refer-

ence voltage at the REF. IN/OUT terminals in the INTERNAL reference mode of operation.

4.4 PHASE SHIFTER (Board No. PS0112A)

The continuously variably phase shifter used in this instrument is based on the following circuit:

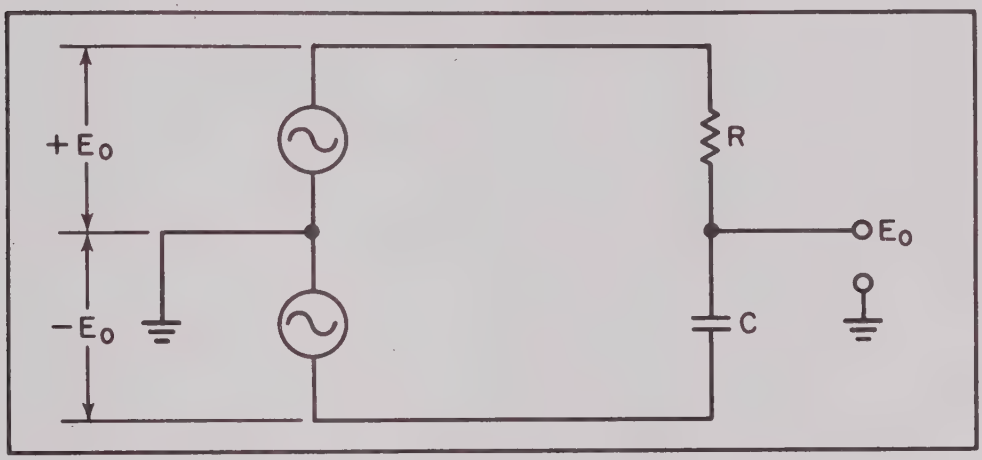

Figure IV-6. PHASE SHIFTER

A series RC combination is driven by a push-pull voltage source whose output is $2E_o$ volts. The output is taken between the RC junction and ground as shown. Upon analysis of this circuit, it is found that the output voltage is E_o, independent of R, C, and the angular driving frequency ω. The phase angle ϕ of the output voltage is given by:

$$\phi = 2 \tan^{-1} \omega RC$$

The phase shifter employed in this instrument consists of a cascade of two such elements. The complete circuit is shown in the diagram of the circuit board No. PS0112A. The first group of three transistors at the left of the diagram and the variable resistance and variable capacitance connected thereto comprise the first phase shift stage, and the next group of three transistors and the variable R and C comprise the second stage. Considering the second stage in detail, the transistor Q306 provides the two voltages of opposite polarity which drive the RC pair. This transistor is driven by Q305. The transistor Q304 is a high impedance load in the collector circuit of Q305. The first phase shift stage consists of a similar set of transistors, Q301, Q303, and Q302, and the associated RC pair. The two variable resistors, continuously variable from zero to 50 k are controlled by the PHASE knob on the front panel. The two capacitors are controlled by switches coupled mechanically to the FREQUENCY RANGE switch.

At the extreme right of the diagram is a diode, D301, and a transistor, Q312. This pair of elements, together with the panel meter (MONITOR METER), form a voltmeter which is used to measure the reference voltage in the REF. position of the MONITOR SELECTOR switch. To the left of this circuit on the diagram is a group of four transistors, Q308, Q309, Q310, and Q311. These constitute an amplifier which is inserted ahead of the diode voltmeter for measuring output of the signal channel amplifier in the SIG. position of the MONITOR SELECTOR switch, and is used to drive the OVERLOAD light in all other MONITOR SELECTOR positions.

4.5 MIXER-DC AMPLIFIER (Board No. M1207)

(Refer to schematic diagram.) The demodulator consists of the six transistors Q401 through Q406 and the associated resistors. Q401 and Q402 are push-pull signal amplifiers. The other four transistors are equivalent to a double-pole double-throw switch. They are connected in pairs and excited by a square wave in such a way that one pair is driven to cut-off while the other pair is conducting. The collector currents of the two signal amplifiers pass through the switching transistors and through the resistors R411 and R412 to ground. If the switching is synchronous and in phase with the signal, half-cycles of one polarity are routed through R411, and half-cycles of the opposite polarity flow through R412. Thus, unidirectional but pulsating voltages of opposite polarity are developed across these two resistors. These voltages are amplified by transistors Q408 and Q409. Some smoothing of the pulsating voltage results from RESPONSE TIME (6 dB/octave) capacitors connected between base and collector on each transistor. The amplified output of these two transistors is impressed on a two-stage push-pull emitter-follower, and current for operating a panel meter and recorder is taken from the emitters of the second stage. Additional smoothing of the pulsating unidirectional current is provided by connecting RESPONSE/TIME (12 dB/octave) capacitors between the bases of the transistors Q410 and Q413.

The square wave switching voltage is generated by the Schmitt trigger circuit which includes transistors Q414, Q415, Q416 and Q417. It is triggered by the sinusoidal reference voltage which has passed through the phase shifter.

There are, of course, two M1207 circuit boards. One demodulates and amplifies the in-phase output of the signal channel amplifier, and the other does the same for the quadrature output.

4.6 OVERLOAD INDICATOR

The utility of a coherent detector of this type in recovering a signal from noise is due to the fact that of the total spectrum (signal-plus-noise) applied to its input, only the signal plus whatever of the noise lies within a bandwidth determined by the output filtering about the signal frequency contributes to the detector output. In order for this to be true it is necessary that the output of the mixer be a linear function of its input. If this is not the case, noise lying outside the bandwidth interval discussed above will contribute to the mixer output through cross-modulation ("noise beating with noise") and other effects; the result being to degrade the sig-

nal-to-noise at the mixer output. Since non-linearity will result from mixer overload, it is important to prevent this from occurring.

In an application where the signal-to-noise ratio is poor, although a long time constant is being used, it is possible that the demodulator is being over-driven even though the output is quite small. The explanation for this is that under conditions of poor signal-to-noise ratio, the part of the demodulator input spectrum which determines the demodulator output (i.e., signal-plus-noise close to signal frequency) contributes only a small fraction of the peak level at the demodulator input. Thus, the peak amplitude of signal-plus-noise at the input can be sufficient to overload the demodulator even though the signal output is small. An overload condition of this type is indicated by the OVERLOAD light.

The circuit of the OVERLOAD indication is shown in Figure IV-7. Its operation depends on the behavior of the point marked "0 V" in the diagram. The demodulator operates by switching the collector currents of Q401 and Q402 alternately to R411 and R412. The demodulation will be linear as long as the collector currents of these transistors are linear functions of their base voltages. The points M1 and M2 are driven by the push-pull output of the signal channel tuned amplifier. Thus the voltage swings on the bases of Q401 and Q402 are equal and opposite (assuming the push-pull output of the amplifier to be perfectly balanced). Under these conditions, when the emitter current of one transistor increases that of the other will decrease by the same amount. The result is that the sum of the two currents remains constant at its quiescent value of about 2.4 milliamperes. When the base of one transistor has risen to about 0.7 volts above its quiescent level, its emitter current will have increased 1.2 milliamperes above its quiescent value. At this point the other transistor will be cut-off. This represents the absolute limit of the linear range of the demodulator. If the current in the conducting transistor increases beyond this point, there will be a change in the sum of the two transistor currents, since there can now be no compensating decrease in the current of the other (cut-off) transistor. It is observed now that the two resistors, R406 and R408, which carry the collector currents of the two transistors, are tied together by a large capacitance, and behave for alternating currents like one resistor. The modulated current which flows in this composite resistor under overload conditions generates an alternating voltage at double the signal frequency. This voltage is amplified and applied to the base of a transistor which is normally biased to cut-off. The overload indicator lamp is in the collector circuit of this transistor, and when an overload signal is applied to the base, current flowing in the collector lights the lamp.

In the discussion above it was assumed that the signal voltages applied to M1 and M2 were perfectly balanced. In practice this will not be the case, and the result will be that a small signal will appear at "0 V" even when the demodulator is operating linearly. The effect of this is to make the OVERLOAD lamp turn on at a signal level slightly below that at which cut-off actually occurs. However, it is to be noted that the transfer characteristic of the transistor begins to become non-linear as cut-off is approached, and therefore, there may be some distortion even though the lamp is not lit. When it is necessary to work close to the level which excits the OVERLOAD lamp, the linearity test described in the Operating Instruction should be performed (see page III-10).

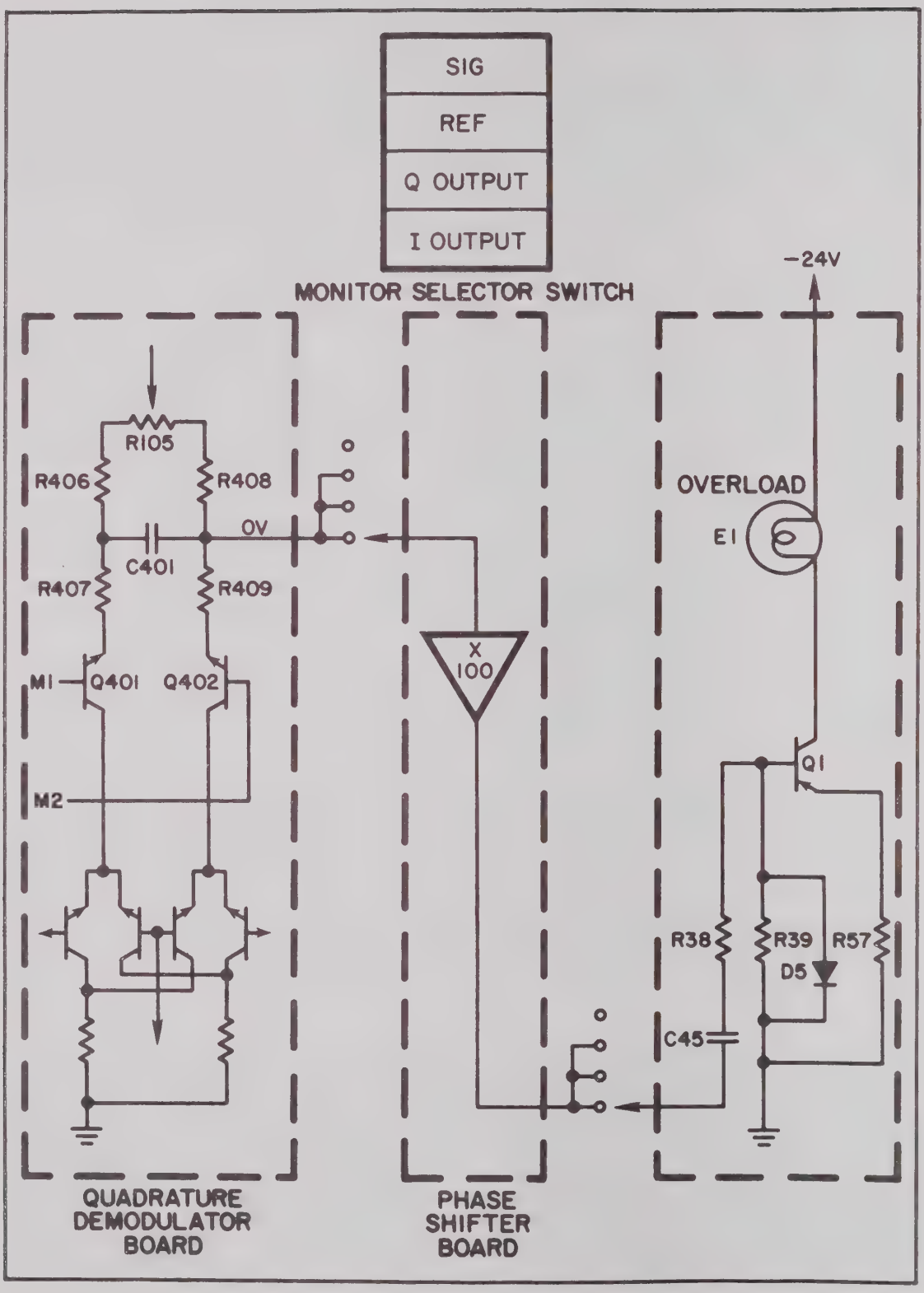

Figure IV-7. OVERLOAD LAMP CIRCUIT

4.7 POWER SUPPLY (Board No. P0114)

This board contains the -24 volt and -20 volt regulated power supplies. The -20 volts circuit operates only the signal channel tuned amplifier. It provides additional power supply ripple filtering and isolation from high level circuits operated at -24 volts. The circuits are completely conventional and require no detailed discussion. The output current (about 250 milliamperes in normal operation) is limited by D508 and R503 to about 500 milliamperes under short circuit. If either supply is shorted, fuse F501 will blow in about one minute. If trouble is encountered with the unit and F501 is found to be blown, locate the short that caused it, and replace F501.

NOTE: UNDER NO CIRCUMSTANCES USE A FUSE LARGER THAN THE ONE SPECIFIED ON THE SCHEMATIC DIAGRAM AS A REPLACEMENT FOR F501. IF AN EXCESSIVELY HIGH CURRENT FUSE WERE INSTALLED HERE A PROLONGED SHORT CIRCUIT COULD RESULT IN THE DESTRUCTION OF Q501, Q508, OR BOTH.

SECTION V
ALIGNMENT PROCEDURE

5.1 INTRODUCTION

The Model JB-6 Lock-In Amplifier is a stable reliable instrument, and as such, will give long trouble-free service. As in any electronic instrument, however, long term changes in component values can take place which will gradually degrade instrument performance. To assure that the instrument continues to perform within specifications, the following alignment procedure should be carried out at regular intervals of about one year. Some of the adjustments will require use of an Extender Board available from PAR. The part number of this board is EB1159-1.

To gain access to the internal adjustments, one must first remove the rear cover, which is held in place by six screws. Also, it should be noted that all of the following adjustments are made with the Response Time Switches set to "OFF".

5.2 POWER SUPPLY

This board is located on the extreme left as viewed from the back of the instrument. It has only one adjustment which is used to set the voltage on the -24 volt line at -24 volts (R511 on the schematic diagram). In making this adjustment, it is necessary to remove the bottom panel from the instrument in order to gain access to the connector into which the power supply board is plugged. Connect an accurate DC voltmeter between pin 15 on this connector and the chassis. Pin 15 is the terminal on the connector closest to the bottom of the instrument. If the meter does not read -24 V, adjust R511. Under these circumstances the voltage on pin 1 of the same connector should read -20 ±2 V. If it is outside these limits, it indicates trouble in the 20 volt regulator which should be corrected.

5.3 SIGNAL CHANNEL TUNED AMPLIFIER

This board is on the extreme right as viewed from the back of the instrument. It has two adjustment trimpots: Q-ADJUST being the lower one (R106) and LOW FREQUENCY BALANCE the upper (R112). In setting these, the LOW FREQUENCY BALANCE should be set first, as this adjustment affects the Q adjustment. The Q-ADJUST has very little effect on the LOW FREQUENCY BALANCE.

LOW FREQUENCY BALANCE (R112) (upper)

This adjustment minimizes the response of the tuned amplifier to frequencies far below the resonant frequency. To adjust it, set the MONITOR SELECTOR switch to SIG., the SIG. LEVEL switch to 1, and the FREQUENCY and FREQUENCY RANGE controls to 150 kHz. Apply a signal of about 1 volt peak-to-peak at 15 to 60 Hz to the signal input terminals. Adjust the LOW FREQUENCY BALANCE trimpot until the output seen on the right monitor terminal by a detector of millivolt sensitivity is a minimum.

Q ADJUST (R106) (Lower)

This adjustment sets the Q of the tuned amplifier. To adjust it, set the MONITOR SELECTOR switch to SIG., the SIGNAL LEVEL control to .02, the FREQUENCY and FREQUENCY RANGE controls to 400 Hz and apply a 400 Hz sine wave of about 1 volt peak-to-peak to the SIGNAL INPUT terminals. Connect a scope or AC voltmeter to the right monitor terminal and ground and adjust either the frequency of the applied signal or the FREQUENCY dial on the Lock-In Amplifier for maximum output. This having been done, vary the Q ADJUST control until the signal level at the MONITOR terminal is the same as that applied to the SIG. INPUT terminal. This sets the on-resonance gain of the tuned amplifier at 50, and since this gain is approximately 2Q it sets the Q at 25. The Q of both tuned amplifiers varies somewhat with frequency. A Q of 25 may be obtained at any frequency in the tuning range by making the adjustment described above at that frequency. Q values between Q=6 and Q=25 may be obtained at any frequency by setting the gain of the tuned amplifier under these conditions to twice the desired Q value.

5.4 REFERENCE CHANNEL TUNED AMPLIFIER

This board is located second from the right as viewed from the back of the instrument. It has three adjustments: Q ADJUSTMENT (R204) at the bottom edge of the circuit board, LOW FREQUENCY BALANCE (R212) at the middle, and INTERNAL OSCILLATOR (R231) at the top.

LOW FREQUENCY BALANCE (R212) (middle)

This adjustment minimizes the response of the tuned amplifier to frequencies far below the resonant frequency. To adjust it, set the REFERENCE MODE switch to SEL. EXT., MONITOR SELECTOR to REF., the REF. LEVEL switch to 1, and the FREQUENCY and FREQUENCY RANGE controls to give 150 kHz. Apply a signal of about 1 volt peak-to-peak at 15 to 60 Hz to the REFERENCE IN/OUT terminals. Adjust the LOW FREQUENCY BALANCE trimpot until the output seen at the right monitor terminal by a detector of millivolt sensitivity is a minimum.

Q ADJUST (R204) (Bottom)

This adjustment sets the Q of the tuned amplifier. The settings of the controls and switches for this adjustment are: REFERENCE MODE switch at SEL. EXT., REFERENCE LEVEL switch at 0.02, MONITOR SELECTOR at REF., FREQUENCY and FREQ. RANGE controls at 400 Hz. Connect an oscilloscope or sensitive AC voltmeter to the right-hand MONITOR terminal and ground. Apply a 400 Hz sine wave of about 1 volt peak-to-peak at the REFERENCE IN/OUT terminals, and adjust the frequency for maximum output. Then vary R204 until the voltage applied at the MONITOR terminal is equal to the applied voltage at the REFERENCE IN/OUT terminals.

INTERNAL OSCILLATOR (R231) Top

The internal oscillator adjustment is made as follows: Set the REF. MODE switch to INT., the REFERENCE LEVEL control to 1, and the FREQUENCY and FREQ. RANGE dials to 400 Hz. Connect an oscilloscope across the REFERENCE IN/OUT

terminals. A sine wave should appear on the scope. Adjust R231 until the amplitude of this sine wave is 5 volts peak-to-peak.

5.5 MIXER-DC AMPLIFIER BOARDS

These boards are located second (In-Phase) and third (Quadrature) from the left as viewed from the back of the instrument. They are basically similar and are aligned by the same procedure. There are four adjustment trimpots. The upper-most one is the HYSTERESIS control (R436), the one below that is the SYMMETRY adjustment (R447), the next lower one the FINE AC BALANCE adjustment (R404) and the lowest one the COARSE AC BALANCE adjustment (R405). These should be adjusted in the following order:

HYSTERESIS CONTROL (R436) (upper)

Turn the SIG. LEVEL control to OFF, the REFERENCE MODE switch to the EXT. position, the MONITOR SELECTOR switch to SIG. and connect an oscilloscope between the long jumper wire closest to the connector pins on the circuit board and ground. With the REF. LEVEL control set to the 1 position, apply a sine wave of about 5 volts peak-to-peak to the REFERENCE IN/OUT terminals. Any convenient frequency between 15 Hz and 15 kHz may be used. Under these conditions a square wave of about 1 volt peak-to-peak should be visible on the scope. Reduce the amplitude of the sine wave applied to the REFERENCE IN/OUT terminals until the Schmitt trigger just stops triggering. Increase the signal level until the Schmitt trigger circuit is just barely triggering. If the square wave is very asymmetrical under these circumstances, adjust the SYMMETRY control until it is reasonably symmetrical. Now again reduce the level of the input signal until the Schmitt trigger just stops triggering. By varying the HYSTERESIS control it should be possible to get the Schmitt trigger to trigger again. Keep reducing the signal and readjusting the HYSTERESIS control until the Schmitt trigger breaks into oscillation or until its output waveform is no longer square but begins to look more like a clipped sine wave (whichever occurs first). Back off from this point until the effect disappears and then one turn further.

SYMMETRY CONTROL (R447) (~~Below~~)(middle)

After making the HYSTERESIS adjustment, increase the signal level slightly until the waveshape is again square. With the scope still connected to the long jumper wire closest to the connector pins, adjust the scope sweep to display ½ cycle of the output waveform. When the duty cycle of the mixer switching waveform is exactly 50%, the response of the mixer to the second (and all other even harmonics) of the reference frequency is a minimum. Switch the scope trigger between + and -. The time for the positive and negative ½ cycles as viewed on the scope should be identical, thereby indicating a 50% duty cycle of the switching waveform. If there is a difference, adjust the SYMMETRY control until they are equal.

AC BALANCE CONTROLS (Bottom 2)

To adjust these controls, set the REFERENCE MODE switch in the INT. position, the FREQUENCY and FREQ. RANGE controls to a frequency of approximately 400 Hz., and the SIGNAL LEVEL control to OFF. Connect an oscilloscope between either

of the Red MONITOR terminals and ground. (If a balanced-input oscilloscope is available, its use is to be prefered and it should be connected between the two red MONITOR terminals). Turn the MONITOR SELECTOR to I OUTPUT when adjusting the balance controls in the in-phase circuit, and to Q OUTPUT when making these adjustments in the quadrature circuit.

(1) COARSE AC BALANCE ADJUST (R405) (Bottom)

Remove the SIGNAL CHANNEL TUNED AMPLIFIER board from the unit (this is the first board on the right as viewed from the back of the instrument) in order to eliminate a noise source to the mixer circuit. Short the bases of Q401 and Q402 together* and adjust R405 until the square wave seen on the scope is a minimum. Since this adjustment is slightly temperature dependent, the unit should be allowed to reach the surrounding ambient temperature before making the above adjustment. Also, upon completing this adjustment, the wire-wound potentiometer, R405, should be tapped lightly to ascertain that the pot wiper is not on the edge of a wire. Observe the output with the oscilloscope for approximately one minute to determine that the output level is not changing. Upon satisfactory completion of this test, this adjustment is concluded. Remove the short from transistors Q401 and Q402 and reinsert the board directly into its connector (applicable only when the extender board is used).

(2) FINE AC BALANCE ADJUST (R404) (upper)

Upon completion of the COARSE AC BALANCE adjustment, the FINE AC BALANCE adjust is used to further reduce the square wave output. This adjustment is made by varying potentiometer R404 until the square wave output as observed on the scope at the MONITOR terminals is a minimum. A slight adjustment of R404 should be made and then time allowed for all circuit elements to reach their steady state conditions before further adjusting R404. This procedure should be patiently continued until the output is minimized. It is conceivable that under certain conditions this adjustment may require as much as five minutes. Upon satisfactory completion of this adjustment, reinsert the SIGNAL CHANNEL TUNED AMPLIFIER removed earlier.

NOTE: Neither of the AC BALANCE CONTROLS should be adjusted indiscriminately in attempting to minimize the square wave output. When it is desired to make this adjustment, the entire procedure given above should be followed.

*Extender board, PAR #EB1159-1 is required.

SECTION VI
WARRANTY

Princeton Applied Research Corporation warrants each instrument of its own manufacture to be free from defects in material and workmanship. Obligations under this Warranty are limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned prepaid to our factory for that purpose within ONE year of delivery to original purchaser. Instruments returned to the factory are accepted only when prior authorization has been given by an authorized representative of Princeton Applied Research Corporation.

This Warranty shall not apply to any instrument, which our inspection shall disclose to our satisfaction, to have become defective or unworkable due to abuse, mishandling, misuse, accident, alteration, negligence, improper installation, or other causes beyond our control.

Princeton Applied Research Corporation reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This Warranty is in lieu of, and excludes all other warranties or representations, expressed, implied or statutory, and all other obligations or liabilities of Princeton Applied Research Corporation including special or consequential damages, and no other source is authorized to assume for Princeton Applied Research Corporation any other liability.

SECTION VII
SCHEMATICS

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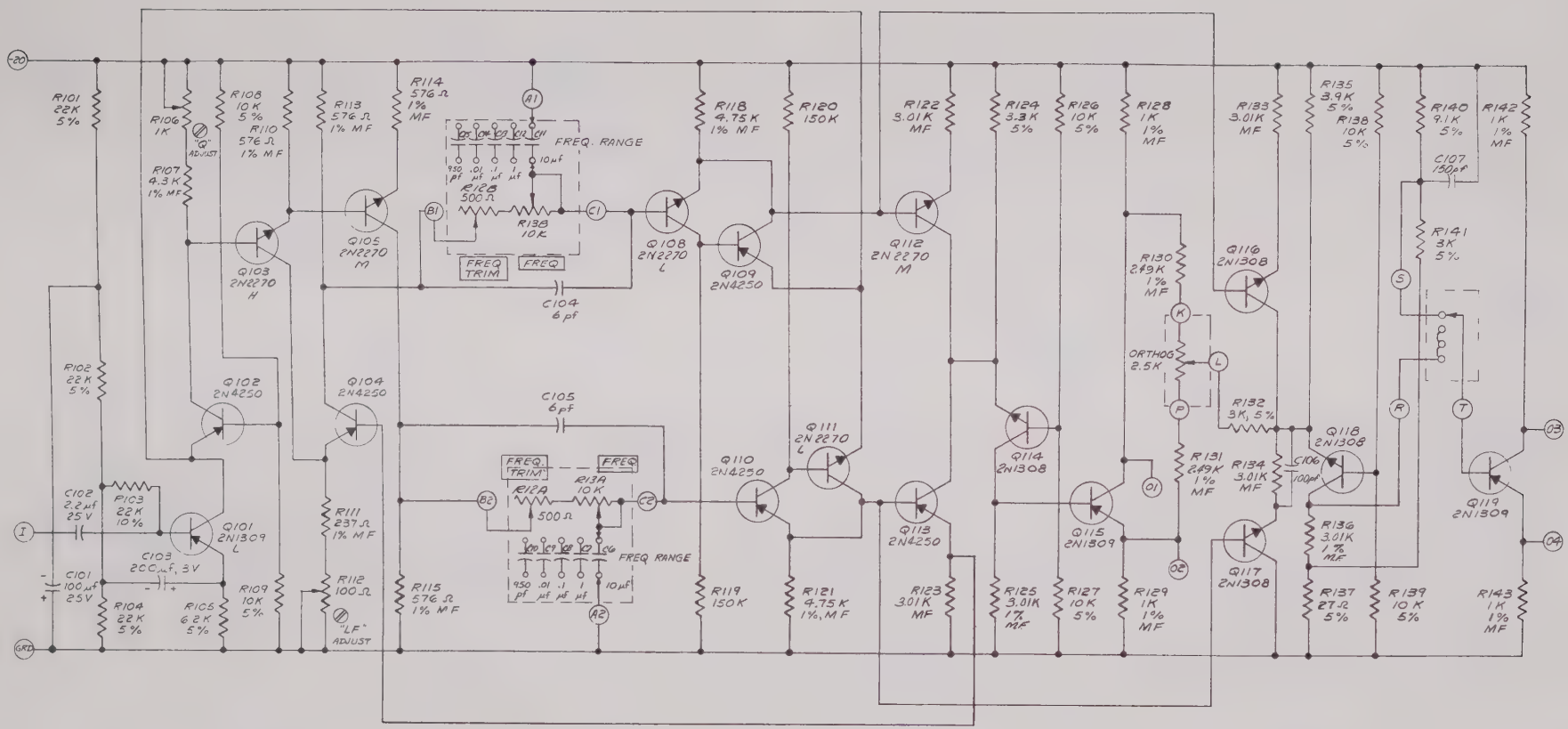
VII-6 ---------- POWER SUPPLY

VII-7 ---------- CHASSIS WIRING SCHEMATIC



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-20	03	T	04	S	N.C.	L	K	P	R	02	01	C2	A2	GRD	B2	B1	A1	C1	I

CONNECTOR PIN CONNECTIONS

NOTES :

1. (H) SELECTED FOR B ≥ 200 AT 5 MA.
2. (M) SELECTED FOR B ≥ 150 AT 5 MA.
3. (L) SELECTED FOR B ≥ 100 AT 5 MA.
4. (MF) METAL FILM RESISTOR.

CIRCUIT BOARD NO. S 1205 B — SIGNAL CHANNEL AMPLIFIER — MODEL — JB-6

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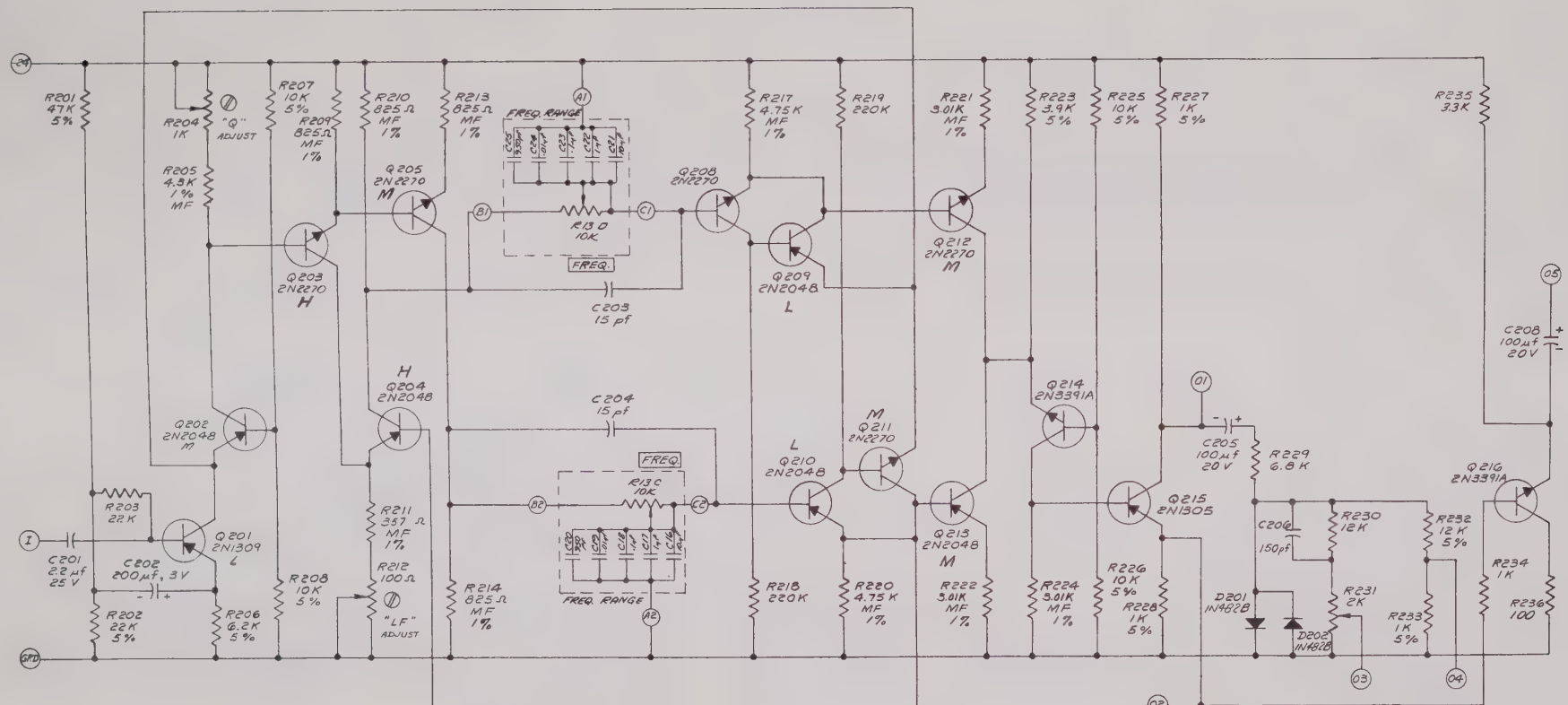

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-24	05	03	02	04	01	N.C.	C2	GRD	A2	B2	B1	A1	C1	I

CONNECTOR PIN CONNECTIONS

NOTES:
1. (H) SELECTED FOR B ≥ 200 AT 5 MA.
2. (M) SELECTED FOR B ≥ 150 AT 5 MA.
3. (L) SELECTED FOR B ≥ 100 AT 5 MA.
4. (MF) METAL FILM RESISTOR

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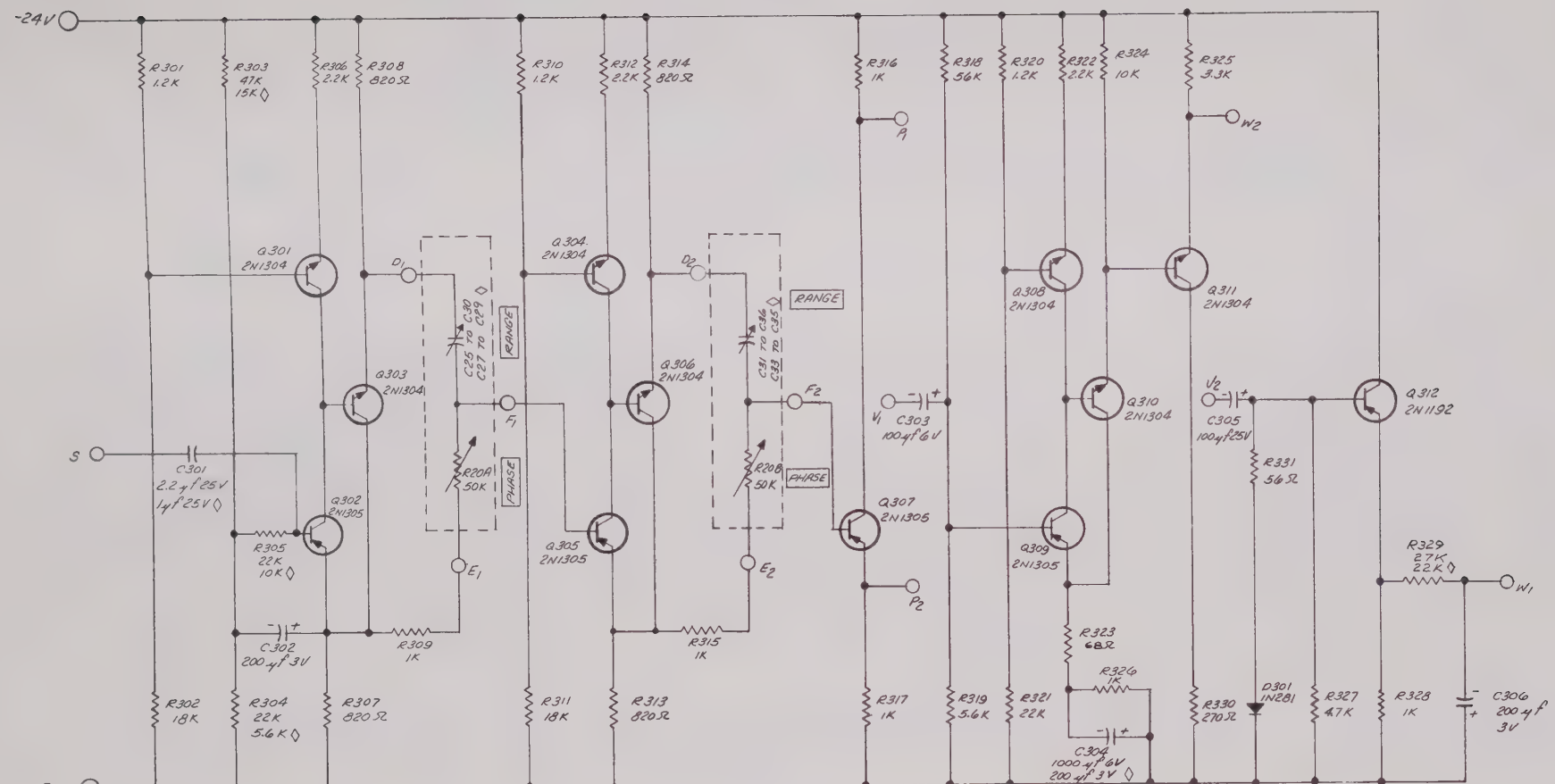
CIRCUIT BOARD NO. R 1206 — REFERENCE CHANNEL AMPLIFIER — MODEL — JB-6

1214 | C | SD | D



1 -24	2 V1	3 W2	4 V2	5 W1	6 P1	7 F2	8 P2	9 GND	10 D2	11 E2	12 F1	13 D1	14 E1	15 S

CONNECTOR 503
PIN CONNECTIONS

NOTE
◊ VALUES USED IN JB4 ONLY

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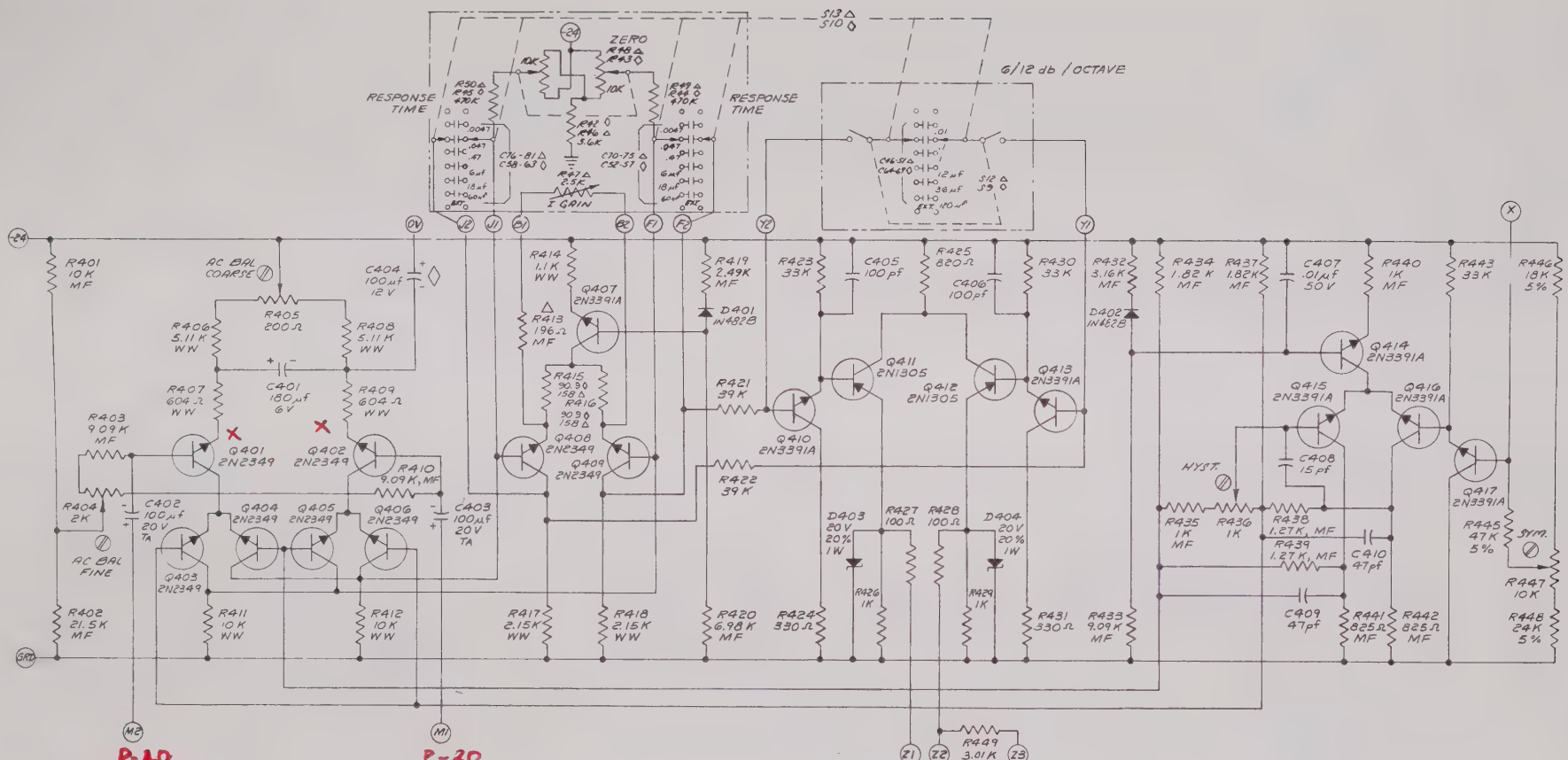
MODELS JB4, JB5 AND JB6

PHASE SHIFTER AND VOLTMETER SCHEMATIC

CIRCUIT BOARD NO. PS0112A



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
-24	X	Z3	N.C.	Z2	N.C.	Z1	N.C.	Y1	Y2	GRD	B2	F1	F2	J1	J2	B1	OV	M2	M1

CONNECTOR PIN CONNECTIONS

NOTES:
1. (MF) METAL FILM RESISTOR.
2. (WW) WIRE WOUND RESISTOR.
3. Δ - USED ON I MIXER ONLY.
4. ◊ - USED ON Q MIXER ONLY.

CIRCUIT BOARD NO. MI 1207

QUADRATURE & IN PHASE MIXER - DC AMPLIFER

MODEL — JB-6

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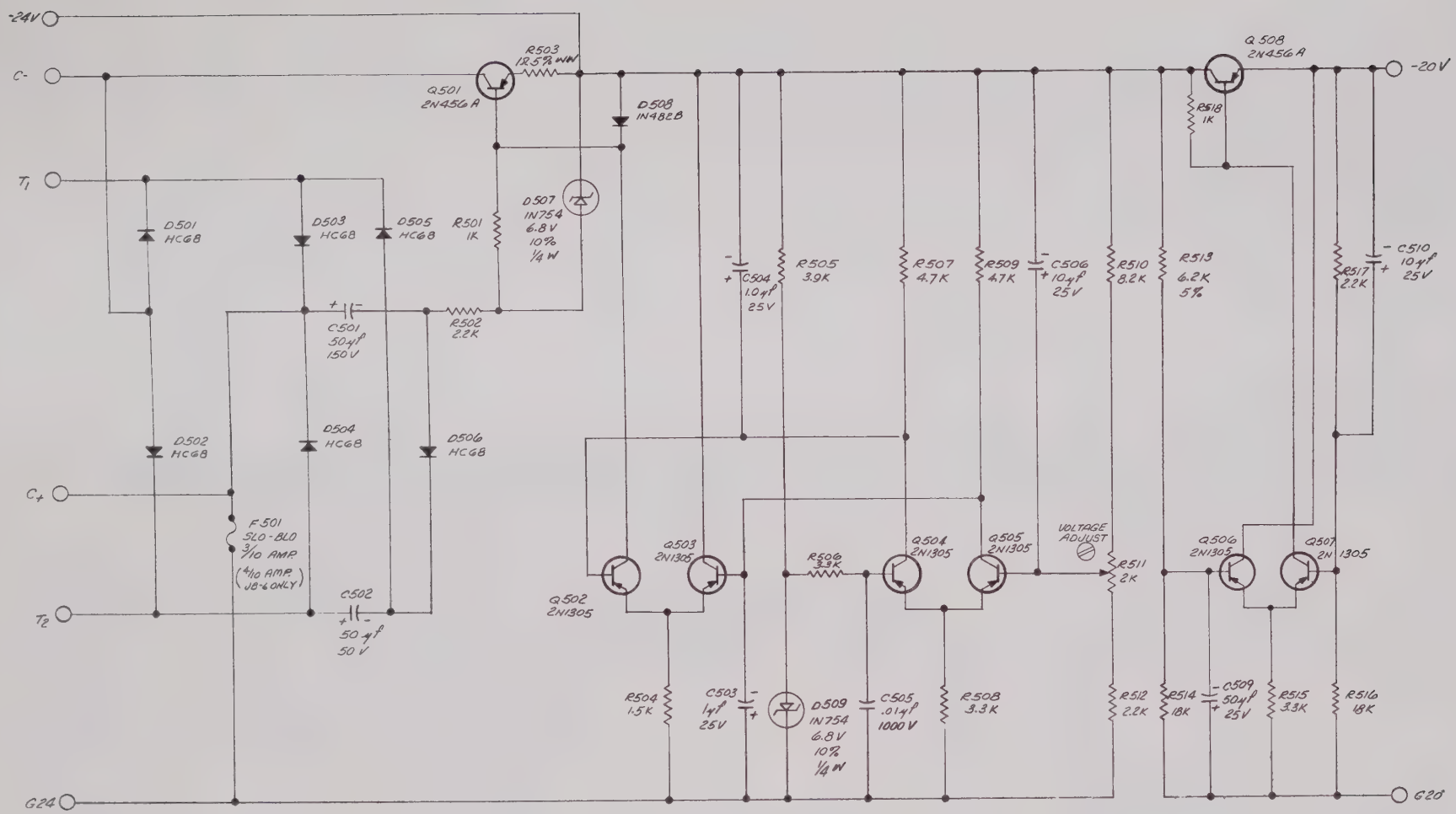

1 -20	2 G20	3 N.C.	4 C+	5 N.C.	6 C-	7 N.C.	8 N.C.	9 N.C.	10 T2	11 T1	12 G24	13 N.C.	14 N.C.	15 -24

CONNECTOR S01
PIN CONNECTIONS

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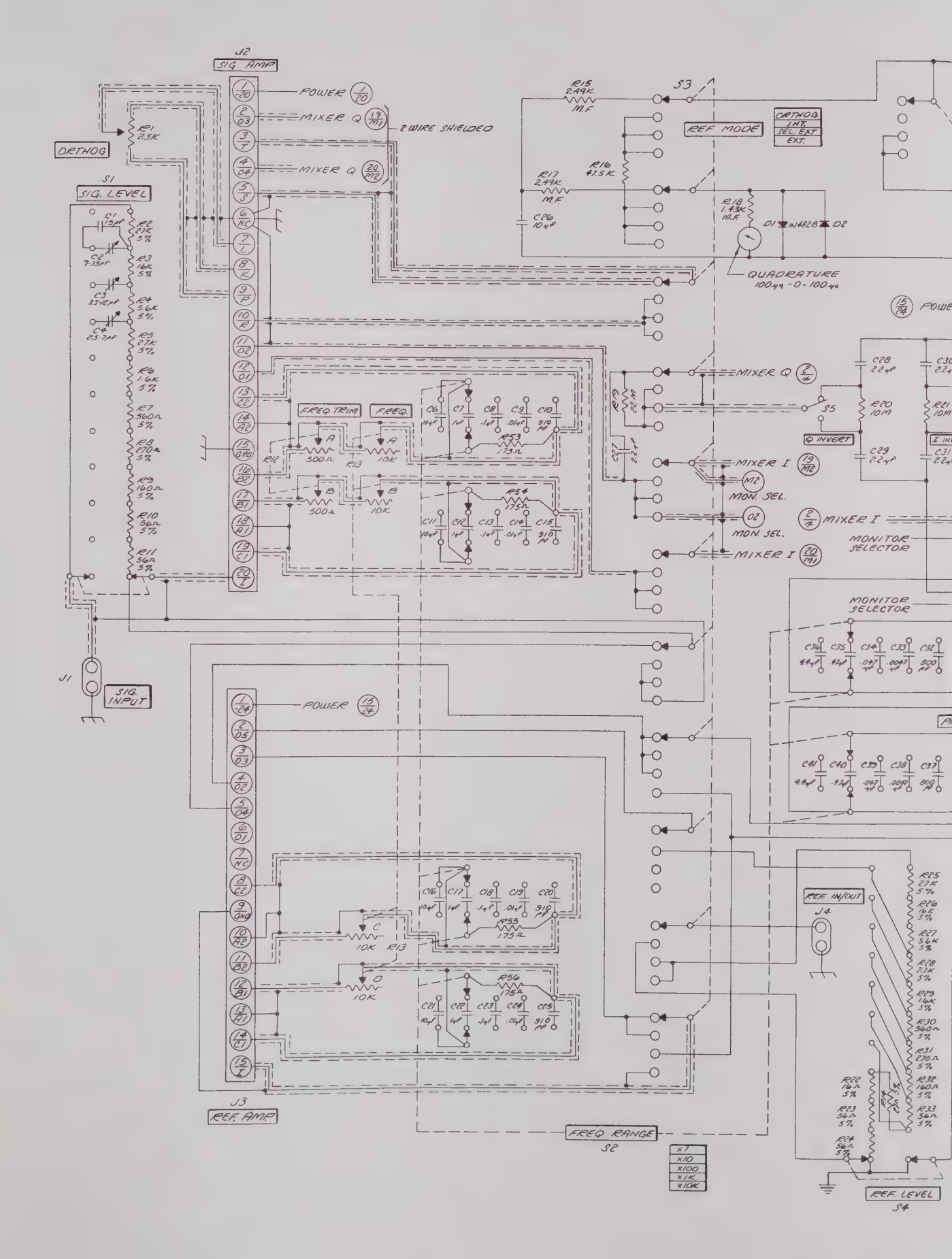
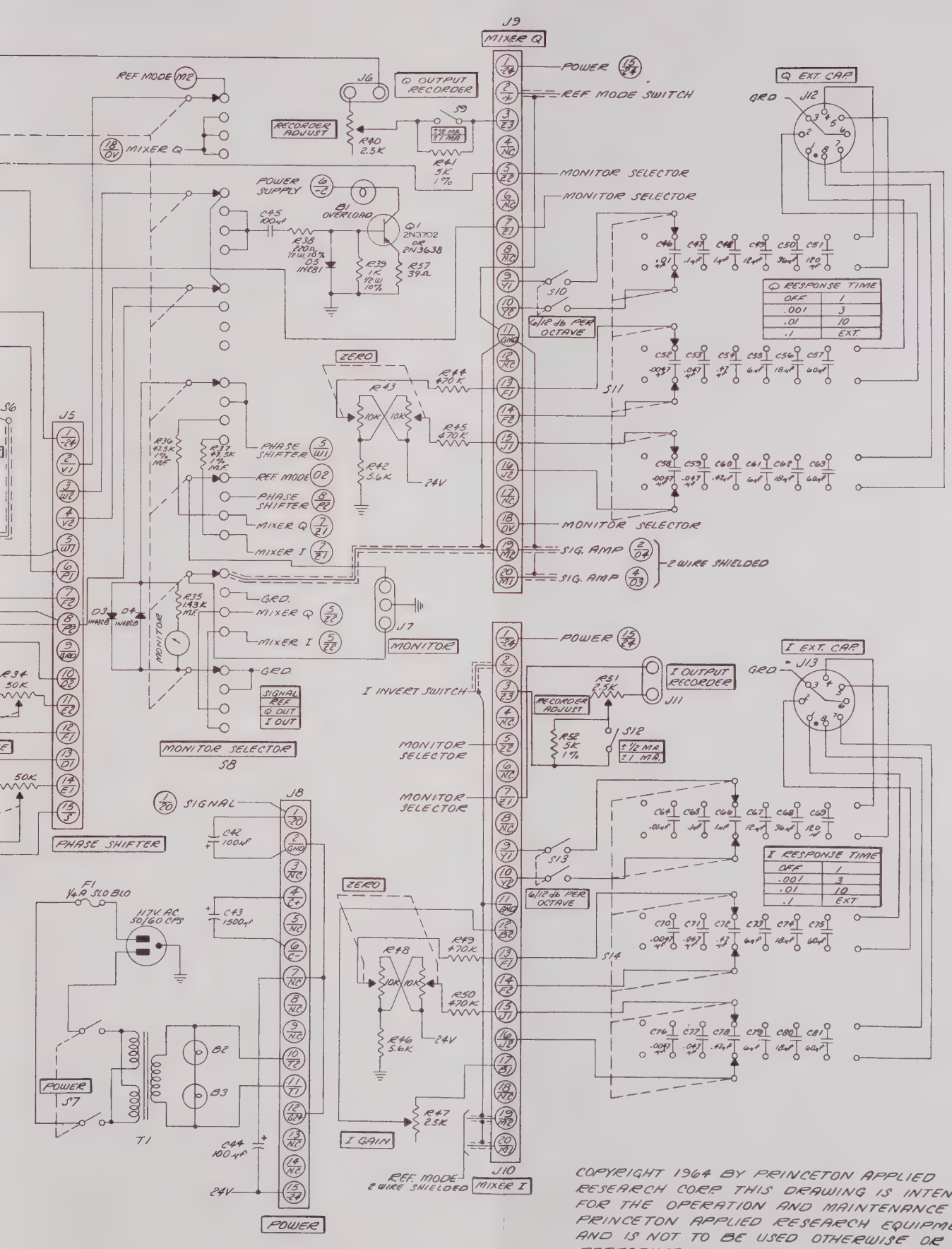
MODELS JB4, JB5 AND JB6

POWER SUPPLY

CIRCUIT BOARD P0114

0104 C SD H


J2
SIG. AMP
POWER
MIXER Q
2 WIRE SHIELDED
MIXER Q
ORTHOG.
R1 2.5K
S1
SIG. LEVEL
S1 15pf
S2 7-35pf
S3 35-16pf
S4 23-7pf
R2 27K 5%
R3 16K 5%
R4 5.6K 5%
R5 2.7K 5%
R6 1.6K 5%
R7 560Ω 5%
R8 270Ω 5%
R9 160Ω 5%
R10 56Ω 5%
R11 56Ω 5%
R15 2.49K M.F
R16 11.5K
R17 2.49K M.F
R18 1.43K M.F
C26 10µF
S3
REF MODE
ORTHOG. INT. SEL. EXT. EXT.
D1 IN4728
D2
QUADRATURE
100µa - 0 - 100µa
FREQ TRIM
FREQ.
A 500Ω
A 10K
B 500Ω
B 10K
R12
R13
C6 10µF
C7 1µF
C8 .1µF
C9 .01µF
C10 910 µµF
R53 175Ω
C11 10µF
C12 1µF
C13 .1µF
C14 .01µF
C15 910 µµF
R54 175Ω
MIXER Q
MIXER I
MON. SEL.
MON. SEL.
MIXER I
MIXER I
MONITOR SELECTOR
S5
INVERT
C28 2.2µF
C29 2.2µF
R20 10M
C27 2.2µF
MONITOR SELECTOR
C36 C35 C34 C33 C32
C41 C40 C39 C38 C37
J1
SIG. INPUT
POWER
J3
REF. AMP
C16 10µF
C17 1µF
C18 .1µF
C19 .01µF
C20 910 µµF
R55 175Ω
C
10K
R13
D
10K
C21 10µF
C22 1µF
C23 .1µF
C24 .01µF
C25 910 µµF
R56 175Ω
REF IN/OUT
J4
R25 27K 5%
R26 16K 5%
R27 5.6K 5%
R28 2.7K 5%
R29 1.6K 5%
R30 560Ω 5%
R31 270Ω 5%
R22 16Ω 5%
R23 56Ω 5%
R24 56Ω 5%
R32 160Ω 5%
R33 56Ω 5%
FREQ RANGE
S2
x1
x10
x100
x1K
x10K
REF. LEVEL
S4



CHASSIS WIRING SCHEMATIC JB-6

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